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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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See Advertisement page 102. 9091

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See Full Page Advt., page 77, June 24.

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See Advertisement page 44. 8469

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See Full Page Advertisement page 72, June 24.

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See half-page Advertisement, page 73, July 8.

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All communications to— H. W. RHID, General Secretary. Head Office— 95, Belgrave Road, Victoria, London, S.W.1.

University College of SWANSEA.

(A Constituent College of the University of Wales.)

APPLIED SCIENCE DEPARTMENTS.

METALLURGY.

Professor:—C. A. EDWARDS, D.Sc. (Manchester).
Lecturer:—H. L. COX, M.Sc. (Wales and Birmingham).
Assistant Lecturers:—A. L. NORBURY, M.Sc. (Manchester); L. B. PFEIL, A.R.S.M.

ENGINEERING.

Professor:—FREDERIC BACON, M.A. (Cantab), A.M. Inst.C.E., M.I.Mech.E., M.I.E.E.
Lecturer in Electrical Engineering:—R. G. ISAACS, B.Sc. (Lond.), A.M.I.E.E.
Lecturer in Civil Engineering:—J. LLOYD DAVIES, B.Sc. (Lond.).
Demonstrator:—J. SELWYN CASWELL.

The College offers a number of exceptional advantages to students who aim at entering upon professional careers in Metallurgy or in Engineering. It is situated in the heart of an industrial area, which includes a large number of works of very varied character, and presents an unrivalled variety of metallurgical practice. The manufacturers of the district, who contribute largely to the support of the College, give the staff and the students of the Applied Science Departments every access to the works, and the managers, engineers and technical officials co-operate with the staff of the College in making visits to Works of practical educational value to the students.

Courses of study are provided (1) for the B.Sc. Degree of the University of Wales in (a) Metallurgy, (b) Civil Engineering, (c) Mechanical Engineering, (d) Electrical Engineering, and (2) for Diplomas of the College in (a) Metallurgy, (b) Civil Engineering, (c) Mechanical Engineering, (d) Electrical Engineering.

Persons who are not desirous of studying for degrees or diplomas may attend selected College Classes, provided they satisfy the authorities of the College that they are qualified to benefit by such classes.

Several Open Entrance Scholarships, each of the annual value of £30, with free tuition, and the South Wales Institute of Engineers' Scholarship in Engineering of the annual value of £70, with free tuition, will be offered for competition in September, 1921.

Particulars concerning admission to the College, and of the Entrance Scholarships, may be obtained from the undersigned.

EDWIN DREW, Registrar.

University College Offices,
Dumbarton House,
Bryn-y-mor Crescent, Swansea. R 406

Inst.C.E. Exams.—Successes as usual last Exam. by Correspondence Coaching. Successes by hundreds, several prizes. Sec. "C" embraces 26 years' professional experience. Address, 7434, Offices of ENGINEERING.

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TENDERS.

Tenders Required for Boiler DEAD WEIGHT VALVES, JUNCTION VALVES, FEED VALVES, and BLOW OFF VALVES, Specification and drawings on application. Tenders to be received not later than August 6th. Apply JOHN THOMPSON (WOLVERHAMPTON), LTD., Engineering Works, Wolverhampton. R 439

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive tenders up to Noon on Wednesday, the 3rd August

Tenders for the Supply of—

1. METALS.
2. BOLTS, NUTS AND RIVETS.
3. WROUGHT IRON OR STEEL PIPING, &c.

Tenders must be made on forms, copies of which, with specification, can be obtained at these offices on payment of 20s. each for Nos. 1 and 2, and 10s. each for No. 3 (which will not be returned).

The Directors do not bind themselves to accept the lowest or any tender.

S. G. S. YOUNG, Secretary.

Offices,
The White Mansion,
9, Petty France,
Westminster, S.W.1.
8th July, 1921. R 435

MUNICIPAL COUNCIL OF JOHANNESBURG.

CONTRACT 175/1921.
MANGANESE STEEL POINTS AND CROSSINGS.

Tenders are Invited for the SUPPLY and DELIVERY of the above. Specifications and Blue Prints can be obtained at the Council's Agents, Messrs. B. W. CARLING & Co., St. Dunstan's Buildings, St. Dunstan's Hill, London, E.C. 3. Early delivery is important.

The lowest or any Tender will not necessarily be accepted.

B. W. CARLING & CO., Agents. R 476

MIDLAND GREAT WESTERN RAILWAY OF IRELAND COMPANY.

OLD MATERIALS FOR SALE.

The Directors of the Midland Great Western Railway of Ireland Company are prepared to receive

Tenders for the Purchase of OLD MATERIALS.

Form of Tender, giving all particulars, can be obtained on application to the STOREKEEPER, General Stores Department, Broadstone Station, Dublin.

Tenders must be posted in time to be received at Broadstone on Tuesday, 26th July, 1921.

(By Order),
PERCY A. HAY, Secretary.

Broadstone Station,
13th July, 1921. R 482

BOROUGH OF AYLESBURY.

ELECTRIC MOTORS AND PUMPS.

Tenders are Invited for SUPPLYING and FIXING FIVE ELECTRIC MOTORS and PUMPS (capable of lifting 70,000 and 80,000 gallons per hour of Effluent, Storm and Tank Water), VALVES, etc., at the Sewage Works, Aylesbury. The Pumps to be of the Centrifugal Type.

Plans and Specification may be seen on application to the undersigned upon payment of £1 1s., which will be returned on receipt of a *bona-fide* Tender and and return of all documents.

Sealed Tenders endorsed "Tender for Electric Motors and Pumps" together with Drawings to be delivered to my office not later than Twelve o'clock, Noon, on Friday, July 30th, 1921.

Contractors desirous of being shown over the site are requested to make arrangements with the Engineer and Surveyor.

The Council does not bind itself to accept the lowest or any Tender.

WM. HAROLD TAYLOR, Borough Engineer and Surveyor.

Town Hall, Aylesbury,
July 11th, 1921. R 426

APPOINTMENTS OPEN.

THE ROYAL TECHNICAL COLLEGE, GLASGOW.

Applications are Invited before August 1st for an ASSISTANT LECTURESHIP in the Department of Civil Engineering. Salary £300 to £350 according to qualifications. Practical experience essential. Particulars may be obtained from the PROFESSOR of CIVIL ENGINEERING, at the College. R 468

ROYAL SCHOOL OF MINES, FRENCHEVILLE RESEARCH FELLOWSHIPS.

The Imperial College of SCIENCE AND TECHNOLOGY, South Kensington, London, S.W.7., with which the Royal School of Mines is incorporated, is OFFERING TWO RESEARCH FELLOWSHIPS, of £300 a year each, tenable for one year and possibly renewable for a second year, to aid in carrying out any investigation or research connected with Mining, Mining Geology, Metallurgy, or the Technology of Oil, which in the opinion of the Selection Committee is of sufficient use or promise.

Applicants who may be Associates of the Royal School of Mines or others, and preferably men with some practical experience, should apply in writing to the SECRETARY of the College (from whom further particulars may be obtained), before 1st September, 1921, giving the nature of the proposed investigation, qualifications for the work and references.

It is anticipated that the Committee will make the awards by the end of November, so that the Fellowships and work may begin on 1st January, 1922. Holders will be expected to devote their whole time to the work which may be conducted at the Imperial College or in special circumstances elsewhere at the discretion of the Committee. R 409

ROYAL NAVY.

Applications are Invited for APPOINTMENTS as INSTRUCTOR LIEUTENANTS in the Royal Navy.

Candidates must be under 30 years of age, have had a University Training, and have taken an Honours Degree in Mathematics, Science or Engineering.

Present rates of pay are from £365 per annum on entry to a maximum of £949 per annum as Instructor Commander. Promotion by selection, to Instructor Captain is also open, with a maximum of £1,377 per annum.

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In cases where it is not possible to provide these the following allowances are paid in lieu:—

VICTUALLING ALLOWANCE £80 per annum.
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SERVANT ALLOWANCE £30 to £60 per annum according to Rank.

For further particulars apply in the first instance to

THE SECRETARY OF THE ADMIRALTY, Whitehall, S.W.1 R 444

EAST LONDON COLLEGE (University of London) Mile End, E.1.

Required, a Lecturer in Civil ENGINEERING. Initial Salary from £500 to £550, according to qualifications. Particulars on application to the REGISTRAR. R 479

THE CITY AND GUILDS (ENGINEERING) COLLEGE.

ELECTRICAL ENGINEERING DEPARTMENT.

The Delegacy are prepared to receive

Applications for a Post as DEMONSTRATOR in ELECTRICAL ENGINEERING. Salary commencing at £300.

Applications, stating age, and giving full particulars of education, training and experience, should be addressed in the first instance, to Professor T. MATHER, F.R.S., City and Guilds (Engineering) College, South Kensington, S.W. 7, before 22nd July, 1921. R 338

LANCASTER EDUCATION COMMITTEE.

STORRY INSTITUTE TECHNICAL AND JUNIOR TECHNICAL SCHOOL.

Wanted for September next:—

(a) ASSISTANT MASTER to teach principally Science subjects.
(b) ASSISTANT MASTER to teach principally Practical Drawing and Metalwork.

Salaries, whether Graduate or Non-Graduate, provisionally according to the Burnham Scale for Teachers in Secondary Schools pending the issue of the Burnham Scale for Teachers in Technical Schools.

Forms of application and particulars should be applied for at once from the undersigned.

GEO. H. MITCHELL, Secretary for Education.

Town Hall, Lancaster,
4th July, 1921. R 365

KENT EDUCATION COMMITTEE.

TUNBRIDGE WELLS AND DISTRICT EDUCATION BOARD.

TECHNICAL INSTITUTE, TUNBRIDGE WELLS.

Required, in September, an ADDITIONAL ASSISTANT MASTER, with a good knowledge of Engineering (particularly Electrical). Preference will be given to a Graduate. Training as well as experience desirable.

Salary in accordance with the Committee's scale (temporarily at rates equivalent to the Burnham Provincial Scale for Teachers in Secondary Schools).

Forms of application and details of duties may be obtained from Dr. J. LLOYD, District Education Officer, Technical Institute, Tunbridge Wells.

H. SALTER DAVIES, Director of Education.

9th July, 1921. R 445

GLAMORGAN EDUCATION COMMITTEE.

APPOINTMENT OF LECTURER IN MECHANICAL ENGINEERING.

The Committee propose to

Appoint a Travelling Lecturer in Mechanical Engineering. Applicants must possess special qualifications for teaching Engineering and Allied Subjects. Successful candidates must devote their whole time to the duties and reside where directed by the Committee, and will be required to commence duties in September next.

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In assessing the commencing salary, regard may be had to previous full-time teaching experience in a recognised efficient school, subject in the case of service under other authorities to a limit of 10 years, and suitable experience in Works will also be taken into consideration. Canvassing will disqualify.

Applications, on forms which will be supplied on receipt of a stamped addressed foolscap envelope, must reach the CHIEF EDUCATION OFFICIAL, County Hall, Cardiff, by the 21st July, 1921. R 415

Applications are Invited for the POST of ASSISTANT to the Metallurgical Inspector at Jamshedpur, Bihar and Orissa, India. The appointment will be for three years in the first instance on a salary of Rs. 475 a month rising to Rs. 575 a month, with a share of fees up to a maximum of one-third of salary and a prospect of further annual increase of salary if the appointment is continued. If confirmed in the appointment, the incumbent would either be placed on a pensionable footing or be admitted to a provident fund to the benefits of which the State would contribute. The duties consist chiefly of the inspection under various specifications of rails, constructural Steel, etc. Candidates should possess a University degree in metallurgy, or be able to give evidence of an equivalent training. It is desirable that the officer appointed should be unmarried and have had not less than 2 years' experience in steel works. He would be required to proceed to India in the Autumn.

Applications should be addressed to the UNDER SECRETARY OF STATE FOR INDIA, Industries and Overseas Department, India Office, London, S.W. 1, not later than 8th August, and should contain full information as to age, qualifications, etc. The names and addresses of three references should also be given. R 477

Railway Traffic Superintendent REQUIRED for abroad, must have good presence and address, knowledge Portuguese or Spanish. Initial salary £700 and house.—Address by letter with copies recent testimonials to H. P., c/o J. W. VICKERS & Co., LTD., 8, Nicholas Lane, E.C.4. R 450

Wanted, Works' Manager for Constructional Steel Work. One possessing extensive experience in all kinds of constructional steel work, bridges, steel pipes, etc. Must have intimate knowledge of costs and production.—Address, stating age, detailed experience and salary required, R 436, Offices of ENGINEERING.

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Power Station Superintendent REQUIRED for the East, to take charge of the running of plant in a Power Station, including Turbo alternations, High Speed Engine Sets, Condensers, Pumps, &c. Must have good knowledge of A.C. 3 phase systems and have had practical mechanical working experience, including High-Tension Switchgear, Transformers, &c. Age 30/35, single. Three years' agreement. Salary £500 upwards and free quarters. Passage paid. Reply, stating age, training and experience, giving dates, to Z. W. 900, c/o DEACON'S, Leadenhall Street, London. R 474

Wanted, for Cement Plant, North of England, a FEW CEMENT MILLERS for Wet and Dry Grinding, also BURNERS. Good men only required. Give full particulars, age, experience, etc.—Address, R 420, Offices of ENGINEERING.

Steel Foundry (Tropenas).—WANTED, a YOUNG CHEMIST, capable of taking charge of Melting Output, about 300 tons monthly. State experience and salary expected.—Address, R 460, Offices of ENGINEERING

Thoroughly Competent Lady CLERK WANTED in advertising department of well-known Engineering firm in Westminster. Shorthand and typewriting desirable but not essential. State age, experience and salary required. —Address, R 454, Offices of ENGINEERING.

Commercial Engineer REPRESENTATIVE REQUIRED. Must be a fully qualified Engineer with adequate drawing office experience (no others should apply). Knowledge of problems relating to pipe lines and pipe joints an advantage. Excellent advancement opportunities for sound engineer able to negotiate and settle contracts. Applications treated confidentially. Write, stating qualifications, experience, age, salary required to MANAGER, THE VICTORY PIPE JOINT Co., LTD., 28, Victoria St., London, S.W. 1. R 451

Wanted Motor Engineer, one who is able to locate faults and take charge of large Motor Repair Shop, dealing with general Repairs to Motor Cars and heavy vehicles. Age 28/30. Salary Rs.600, rising to Rs.700, three years' agreement, free second-class passage.

Write, stating age, full details of training and experience, with dates, to

THE OMIAR FOUNDING & ENGINEERING CO., LTD., Mazagon, Bombay. R 466

Heating Engineer Wanted at Once to take charge of Department engaged principally in laying out High Pressure Hot Water Stoving Plants. State age, experience and wages required.—Address, R 453, Offices of ENGINEERING.

Engineer Wanted, Midland area, to take charge of moderate size works producing high-class speciality (not mass production). Good technical qualifications and engineering experience. Age about 30/35. Salary £400 per annum with prospects.—Address, R 352, Offices of ENGINEERING.

Young Structural Engineer with sound technical education, REQUIRED for temporary job. Experience of Transporter or similar design or erection desired.—Address R 371, Offices of ENGINEERING.

Young Electrical Engineer with sound education in mathematics and physics, REQUIRED for temporary design job. Practical experience of high voltage work an advantage.—Address, R 372, Offices of ENGINEERING.

BIRMINGHAM MUNICIPAL TECHNICAL SCHOOL.

Wanted Mechanical Engineer (age 25 to 35), to take charge of heating, ventilating and electric lighting plant, including Babcock boiler, gas engines, and electric generators. —For full particulars, apply SECRETARY, Municipal Technical School, Suffolk Street, Birmingham. R 370

BURGH OF PAISLEY.

INCHINNAN OPENING BRIDGE.

Wanted, Resident Engineer, with experience of Bridge Construction, to superintend erection of Swing Bridge at Inchinnan. Applications, stating experience and salary, to be lodged with the Subscriber.

JAS. F. JOHNSTONE, Municipal Buildings, Town Clerk. Paisley,
9th July, 1921. R 441

Marine Engineer Required, with good general education, with Shop and Drawing Office experience, capable of handling all classes of Ship Repairs. Age 26/30.

Salary Rs.600, rising to Rs.700, three years' agreement, free second class passage.

Write, stating age, full details of training and experience, with dates, to

THE OMIAR FOUNDING & ENGINEERING CO., LTD., Mazagon, Bombay. R 465

Wanted for London E.C. district, JUNIOR DRAUGHTSMAN, with experience in detailing electric cranes and hoisting machinery. State age, experience and salary required.—X. F. 888, care of DEACONS, Leadenhall Street, E.C. 3. R 407

Wanted, Structional Steel Detail DRAUGHTSMEN.—Apply, giving full particulars, to GEO. SANDS & SON, LTD., Colwick, Nottingham. R 458

INSTITUTION OF MECHANICAL ENGINEERS.

SUMMER MEETING.

(*Concluded from page* 72.)

HAVING in our previous issue given a report of the four meetings held simultaneously on Thursday, 30th June, we now give our report of the meetings of the four sections on Friday, the 1st inst.

WASTE HEAT UTILISATION.

On the date just named, a meeting was held at 10.30 a.m. in the Library, under the chairmanship of Sir John Dewrance, to discuss a paper on "Waste Heat Utilisation," by Mr. Robert Nelson. The author pointed out that waste of heat implied waste of coal, and the question therefore affected directly or indirectly every industry in the country. The first of what are now known as waste heat plants was put down many years ago by the Priestman Power Company at Blaydon-on-Tyne. There were at the present time 11 waste-heat stations on the North-East Coast which produced many millions of kilowatt-hours of electrical power per annum. As regards the utilisation of waste heat, it was best to organise all works as far as possible on a self-contained basis, so that each could use its own excess of heat for some other purpose. The great producers of surplus heat were the coke ovens and the blast furnaces. Both of these branches of industry were engaged in processes necessary for the ultimate production of finished steel, an operation which required large quantities of heat. Blast furnace owners and steel makers now realised that their businesses should be combined, in order to procure economy of fuel and therefore cheapness of production. The ideal installation would be one in which coal and ore were the raw products received, and in which finished steel was turned out. The works of the Skinningrove Iron Company afforded the best example of work along these lines in this country. It should be remembered, however, that the periods of production of waste heat available for producing power in any industry rarely coincided with the periods during which power was required in that industry. This difficulty might be got over by connecting the works with the electrical power generating stations, so that the works could supply power to the surrounding district when they had it in excess, and could draw upon the central station when they required more power than they could produce themselves at any time. It was often the best way, in reorganising a works, to make a clean sweep of existing obsolete plant, rather than to endeavour to modernise it, a process which involved the perpetuation of equipment which should properly be discarded. The problem of utilising the waste heat of isolated coke-oven plants could be met in some instances by selling this potential heat in the form of coke-oven gas. The main points for which the speaker contended, was that waste heat should be abolished, and that plants should be so organised as to require for the industry the minimum consumption of raw fuel. Radical changes of practice might be costly, but if they economised fuel the capital expenditure was well justified.

Mr. F. H. Trevithick, called upon by the chairman to open the discussion, said that he could only speak of experience with regard to utilising the waste heat of locomotives. He had found from experience that locomotives fitted with waste-heat superheaters required from 20 per cent. to 25 per cent. less coal for the same work, as compared with those without superheaters. He had fitted up 35 locomotives in this way and had also tried the effect of heating the air before it entered the furnace, as well as heating the feed water by means of the heat of the smoke-box gases. The feed water had been raised to 280 deg. F. by this means, and whether the waste gases were used for heating steam or water, about the same economy resulted. After about 60,000 miles on the road, the steel tubes of the Schmidt type of super-heaters failed and it was generally necessary to pull them all out of the boiler tubes to find which had gone wrong. Since the speaker had left the Egyptian railways, many ways had occurred to him which would bring about better results in locomotive economy. It was known that the flow of the gases through a locomotive boiler was very unequally distributed among the tubes, and he would modify the chimney in such a way as to equalise the flow, and make all tubes work equally effectively.

Mr. D. E. Marsh said that the effect of superheater tubes in a locomotive boiler was to make more of the gases go through the lower boiler tubes. Great economy could be effected by heating the feed water to just below boiling point before it entered the boiler; this and superheating the steam, had effected a revolution as regards locomotive efficiency. Pre-heating the air before it entered the furnace was difficult in a locomotive, but it produced some economy.

Mr. H. M. Ridge pointed out that 2,000,000 tons of coal are gasified annually in producers to provide heat for the manufacture of steel, in spite of the fact that we had a vast quantity of valuable coke-oven gas still going to waste. In a combined blast furnace plant and steel works in Belgium, coke was obtained from Westphalia. The blast-furnace gas was cleaned and so efficiently utilised that it supplied all the furnaces and also generated electricity for the rolling mills. After being used in a gas engine, the gas could still perform further functions, as the exhaust from the engine could be used to raise steam in waste-heat boilers. Gases left the regenerators of steel furnaces at a temperature varying from 800 deg. to 1,080 deg. C., and the amount of heat so lost was very great. In this country our coke ovens and blast furnaces would not only supply all the gas required for heating furnaces, but a large excess of power could be produced for delivery to central stations.

Mr. S. Utting called attention to a drawing placed in the exhibition in another room, which showed a boiler-house at the Hague in which 120,000 lb. of air per hour, required by the furnaces, was all pre-heated by means of the flue gases. On an 8-hours' test, a Belleville boiler had shown a thermal efficiency of 60·2 per cent. when operated in the ordinary way. When the air required for combustion was preheated by the flue gases the efficiency had risen to 69·2 per cent., with a resulting economy of 13 per cent. in fuel. It was a proved fact that by raising the temperature of the air to the fires, the furnace temperature was increased, and the exit temperature of the gases leaving the boiler was diminished. This result was due to the fact that the transference of heat from the fire to the boiler increased with rising temperature much more rapidly then the temperature rose.

Mr. Handoll considered that a good deal of exaggeration had occurred concerning the waste of heat in boiler plant when properly operated. The dirty condition into which the tubes and heating surfaces of many boilers were allowed to get was a source of great avoidable loss.

Mr. Sarjant, referring to open-hearth furnaces, said that when properly operated, the temperature at the base of the checkers was only about 400 deg. to 500 deg. F. If one had a well-designed furnace and checkers the loss of heat should not exceed 20 per cent. He did not think any appreciable economy could be obtained by heating the air underneath the grate.

Mr. R. H. Parsons said that little had been mentioned concerning the saving of heat in electric power stations. In one plant with which he was familiar, the engineer had carried the heated air which had passed through the main generators into the boiler room, and used it as forced draught. An appreciable economy was claimed for the method, and it certainly had the indirect advantage of reducing noise in the engine-room, and keeping the temperature there lower than it would otherwise be. In the same station a large heater, working at atmospheric pressure, was placed in the flue on the chimney side of the economisers. This was composed of old boiler drums piped together and had a storage capacity for about 100,000 lb. of hot water. Into this heater every single clean-water drain was led, including even the safety valve blow-offs. The condensate from the turbines first passed through a low-pressure economiser, which had served its normal useful life, into the open heater. Thence it was pumped through the high-pressure economisers into the boilers. The underlying idea was to run with the lowest possible condenser temperature, and consequently the highest possible vacuum, and to do the whole of the feed-heating by the heat in the flue gases. The flue gases were reduced in temperature to about 220 deg. F. before being put up the stack by the induced draught fans, and the plant was the most efficient of its size which the speaker had ever observed. It might be mentioned that the station contained three turbines with an aggregate rated capacity of about 6,000 kw., and having an annual output of about 13,000,000 kw.-h.; and the total number of men on the night shift was only two, one in the engine-room and one in the boiler room. A third man had subsequently been added for safety's sake. What station engineers really wanted was some way of using the waste heat carried away by the circulating water. The engineer to which he had referred intended to use it for growing tomatoes. It had often occurred to the speaker that there must be some simple electrolytic or electrochemical process which could be worked in conjunction with power stations, so that during the hours of normal light load, the plant could be kept running at something like its full capacity. A station such as the one to which he had referred, which had a coal consumption of 10,000 lb. per shift plus 2·06 lb. per kilowatt-hour generated, would obviously run at full load with a coal consumption of 2·25 lb. per kilowatt-hour, whereas at one-quarter full load it would take practically 2·9 lb. per, kilowatt-hour. The fuel saving, therefore, by keeping the station loaded, was very great indeed.

Mr. Robert Nelson replied very briefly to the discussion, instancing a case in Glasgow where 30 per cent. of the fuel had been saved by utilising the waste heat from a furnace. As regards promoting power station economy by employing some electrochemical process to absorb power at times of light load, a good deal had been done in this direction on the North-East Coast, where the power stations were worked in close conjunction with electrochemical industries.

SUPERHEATING.

The second discussion in the Library on the morning of the 1st inst. was on "Superheating," a paper on this subject being read by Sir Henry Fowler, K.B.E., Member of Council. The chair was taken by Sir John Dewrance.

Sir Henry Fowler mentioned that superheating of steam was by no means a new idea, but that its practical application had been hindered chiefly by difficulties of lubrication. The advantages of superheating were that the volume of the steam was increased and that its fluidity was greater, as compared with saturated steam. It must be remembered that the increase of volume was obtained by the absorption of comparatively few heat units, so that superheated steam did not contain the same available heat as an equal volume of saturated steam. The lubricating difficulties of steam turbines had been solved by the use of pure mineral oils, but in these the oils did not come into direct contact with any steam. In locomotive cylinders the best results had been obtained with compounded oils, but one trouble with these was the formation of a deposit in the cylinders and ports. Ten years ago turbines used a maximum superheat of 150 deg. F., while locomotives often went up to 300 deg. F. superheat, but now turbines used steam as highly superheated as locomotives. The saving by the use of superheated steam in turbines was about 1 per cent. for every 10 deg. of superheat and there was also a diminution of erosion of the low-pressure blades. On land boilers the design of a superheater presented no difficulty, but in locomotive practice the only practical design consisted in placing the superheater tubes inside certain boiler tubes made specially large for the purpose. The speaker had been criticised formerly for using cast-iron headers for his locomotive superheaters, but these had been in use now for ten years and had given no trouble.

Professor Low said that all engineers now admitted the advantages of superheating. He could only deal with the subject from the schoolmaster's point of view. The saving due to superheat was greater the lower the pressure of the steam, and the saving attained in practice was always

greater than the theoretical saving, due to the extra available heat in the steam. The theoretical saving to be obtained by superheating steam at 200 lb. per square inch by 360 deg. F. was, speaking from memory only, about 8 per cent., whereas in practice an economy of something like 14 or 15 per cent. was obtained with this superheat. The reason for this might lie in the fact that ordinary steam contained water, and the heat in a drop of water at 100 lb. pressure was about one hundred times as great as in the corresponding volume of steam. Hence water escaping past a valve or piston carried away one hundred times as much heat as the same volume of steam would do. As there could be no water with superheated steam such steam would, therefore, be free from the heavy losses due to water leakage.

Mr. Thos. Sugden mentioned that superheating had in many instances earned a bad name for itself by being injudiciously applied. Steam temperatures up to 750 deg. F. were all right for turbines, with drop-valve engines the upper limit was from 600 deg. F. to 650 deg. F., and with Corliss engines about 500 deg. F. On locomotives force-feed lubrication, bringing the oil right to the spot where it was wanted, had to be adopted if superheating was to be successful. He had found it possible to transmit superheated steam great distances without losing the superheat. It should be noted that, in an ordinary boiler installation, the superheat of steam rose rapidly as the output of the boilers was raised.

Mr. F. H. Trevithick said he had only had experience of one locomotive with a high degree of superheat. He believed in getting all the heat one could out of the flue gases, and had found that with feed-water heaters on a locomotive the feed could be put into the boiler at a temperature of 280 deg. F. The speaker had 30 locomotives fitted with such feed heaters, and considered that by the use of a feed-water heater and a superheater the coal consumption of a locomotive could be reduced by 30 per cent. He had experimented by running locomotives with as many as 100 tubes plugged up, and found that practically as good results were obtained in ordinary working as when they were all open. This experiment confirmed the view that many of the tubes did very little work. He did not recommend reducing the number, however, but would modify the draught so that the flue gases flowed through all of them equally. This would eliminate the excessive wear on the top half of some of the tubes.

Mr. D. E. Marsh said he had been one of the pioneers in superheating for locomotives in this country, but his experience was somewhat out of date now. He had found the greatest difficulty with lubrication, except with pure mineral oil, when the temperature of the steam was raised to 600 deg. F. or 650 deg. F. Unless pure mineral oil was used, and was brought positively to the surfaces to be lubricated, success was impossible. For high superheat on locomotives piston valves were essential. The speaker thought that the benefit to be expected, theoretically, from superheating was somewhat greater than the figure Professor Low had mentioned. The great benefit which locomotives obtained from superheating might be due to the fact that the normal steam from locomotive boilers was very wet, on account of priming. Was not the expansion curve of the steam in a locomotive cylinder far below the adiabatic? The speaker had found no difficulty with cast iron headers for locomotive superheaters, because the castings were small ones, but steel was essential for large castings such as were used for steam turbine casings. With regard to the quality of metal necessary to withstand superheat, he instanced the case of a German-built turbine, made by the A.E.G. Company, in which many rows of blades had to be completely renewed. It had run continuously for five years. The speaker thought that the Germans did not understand how to make the high class of steel necessary for such a job.

Mr. F. H. Livens asked whether when superheaters were installed it was considered an advantage to reduce the heating surface of the boiler, so as to have wetter steam going to the superheater. The German practice seemed to be to reduce the heating surface for a given size of grate under these conditions.

Mr. L. Barrow inquired whether the author could give particulars of any experiments which would justify his statement as to the extra fluidity of superheated steam.

Sir Henry Fowler, in reply, said he was rather sorry that the discussion had turned so much on superheating in connection with locomotives, as he had hoped to hear from power station engineers, who had a vast experience with superheaters. It was possible that much of the benefit which a locomotive derived from superheating was due to the fact that ordinary steam from such boilers might be heavily charged with moisture. There was no difficulty in using flat valves, or possibly Corliss valves, with a high superheat, if a suitable lubricating oil was forced to the working faces. He had run a slide valve locomotive with a superheater and no trouble had occurred. Mr. Trevithick had raised the question of feed-water heating on locomotives, but devices for this purpose added materially to the weight. For bearings a pure mineral oil was wanted, but a compounded oil was necessary for surfaces working in steam. The speaker had measured steam temperatures up to 770 deg. on locomotives, but it was difficult to get pyrometers to stand the conditions for long. As regards fluidity of superheated steam, this was difficult to define quantitatively, but it was an established fact that the passage of superheated steam pass the pistons of an engine at the beginning of the stroke was greater than that of saturated steam. With regard to the point raised by Mr. Livens, he did not agree with the idea that the heating surface of a boiler should be reduced when a superheater was fitted. When he said that superheat had reduced the erosion of turbine blades, he had the low-pressure blades in mind. With initial superheat these blades would be working in drier steam, and it was the wetness of the steam which caused erosion.

After a vote of thanks had been passed to the author on the motion of the Chairman, a similar vote was passed to Sir John Dewrance for taking the chair, on the motion of Sir Gerard Muntz.

LIQUID, COLLOIDAL AND POWDERED FUELS.

Mr. Loughnan Pendred presided on the morning of the 1st inst., in the section meeting in the Reading Room, when Dr. Ormandy, F.I.C., presented the first paper with the above title. The main advantages of liquid fuels, Dr. Ormandy said, was a heating value of 18,000 B.Th.U. per pound, as compared with coal, 12,000 B.Th.U. Oil was also cheaper to handle, a greater number of heat units could be stored in a given space, and it was easier to burn efficiently and to regulate the air-fuel ratio. The furnaces demanded less labour, the radius of a ship was increased. For marine steam-raising the use of oil-fuel would grow until the rising prices counterbalanced the advantages. The recent coal situation had extended the use of oil. For many industrial operations, particularly where control of the oxidising or reducing flame was essential and for heating bars and billets, oil was very suitable; but it would be an absurdity to speak of replacing coal by oil. The internal-combustion engine gave from 20 per cent. to 35 per cent. of the fuel heat value on fly-wheel energy, whilst the steam engine rarely exceeded 10 per cent. But Diesel engines and semi-Diesels should only burn oils too heavy and impure for other oil engines; a wider range of fuel was being found for these engines, and the needlessly heavy and expensive engines were being replaced by lighter engines for higher speeds. Tar oils were also utilised under boilers and, to a lesser degree, in engines.

Powdered coal resembled liquid fuel inasmuch as it could be injected through nozzles. It had long been used in the rotary cement furnaces and, in America especially, also for steam-raising. The coal had to be dried and ground to a fineness that only a few per cent. were left on a 200-mesh sieve. The cost of drying and grinding had been brought down to 3*s.* or 3*s.* 6*d.* per ton; the bulkiness of the fuel and the necessity of providing good airtight connections between store tank and main were drawbacks. Coal could probably be burnt more efficently powdered than on the ordinary grate, but the saving was doubtful considering the cost of plant and installation. Dried and powdered peat was used on Swedish railways, a fact not to be overlooked. The use of a mixture of coal dust and fuel powder refuse with liquid fuel had been proposed by Bennett already in 1894. Since oil could not displace coal it would be desirable to secure the advantages of a liquid fuel by using such mixtures. But there was the question of the settlement of the solid out of the liquid. If coal dust were ground down so that all passed a 100-mesh sieve it would not settle out of a heavy fuel oil in several days, and would then form a paste. The mixture could be transported by wagon and could be discharged after standing for many days by passing compressed air, probably also by hot flue gases at 150 deg. F., through perforated pipes into the mixture. A mixture of 40 per cent. of coal dust with heavy oil would be cheaper than oil alone, and the arrangements adopted for oil-firing could remain in use. The coal would not affect the viscosity of the oil unless it were in a really colloidal state, but it would apparently absorb the more volatile oil constituents and reduce the flash point, though that was not yet actually proved.

Finely-divided suspensions of coal, lignite and the like could also be stabilised by additions of soap or of constituents which would charge the particles electrically. But the cost would be heavy, and Dr. Ormandy thought mechanical means of maintaining the coal in suspension preferable and more likely to satisfy the authorities, especially for marine uses. The question where and when to mix the coal and oil was important. One could mix the two in a tube mill or grind the coal separately; simple mechanical mixture seemed sufficient, and one need not bother about attaining a so-called colloidal condition. The use of colloidal coal fuel—wrongly so termed—in engines of the Diesel or semi-Diesel type seemed to be hopeless. The ash-limit of fuels for such engines, fixed by bitter experience, was 0·06 per cent.; ordinary coal contained 3 per cent. of minerals.

The chairman thanked Dr. Ormandy for his remarkably good *précis* of the problems of the whole subject, and called upon Sir Henry Fowler to open the discussion. Sir Henry, joining in the compliments, said that they had found the ratio of the heat values of oil to coal to range between 1·5 and 1·75 rather than Dr. Ormandy's 1·75 to 2. Dr. Ormandy had given the specific gravity of fuel oils; engineers spoke of efflux times at 60 deg. F., but some oils were too thick for that classification. The whole problem was financial; there was no difficulty about oil burners. Powdered coal had been used on locomotives in America during the war, but dust and slag caused trouble. On the Rumanian railways both oil and powdered coal were used, but not mixed.

Mr. P. V. Vernon confined his remarks to a coal-pulverising machine invented by Mr. Charles E. Blyth of Messrs. C. Nelson & Co., cement manufacturers, Stockton, specially for cement kilns. The machine was of the centrifugal type and acted in two stages. In the first stage the fuel and air expanded, and the coal was dried and slightly disintegrated; the real powdering took place during the second contracting stage. They had used coal with 20 per cent. of ash. The material they had lately taken from a rubbish heap looked more like soil than like coal, and was very moist; when blown into the kilns it failed to give enough heat to produce a good clinker; on injecting 0·7 per cent. of paraffin (reckoned on the weight of coal) together with the coal, the clinker became good, but the flame darkened again as soon as the oil was turned off. The small amount of oil seemed to enable the coal particles to flash up quickly. With the ordinary coal they had more than halved the fuel consumption by powdering it, and they had no difficulty with the dust now. Mr. M. A. Lawrence inquired about the ash. They had been burning a very fine fuel, he said but had been stopped by an injunction, because their chimney discharged a fine powdered dust.

Mr. Pendred (Chairman) gave some particulars, he had received about American practice, adding that his information referred to 1918. Powdered fuel was used on the locomotives of several American railways, also on the Central Railway of Brazil—Sir Henry Fowler interposed the remark that the railways were said to have abandoned the powdered fuel. There had been trouble with flashing back—

with grinding, Sir Henry thought—and as the fuel could not be transported over great distances it had been stored, when explosions caused official interference. Powdered anthracite would not maintain a good fire unless mixed with 40 per cent. of bituminous coal. They seemed to be going forward rapidly with the use of powdered coal in America, though, perhaps, not on locomotives. Mr. Pendred quoted some efficiency figures with due reserve.

Mr. Percy W. Griffin said that much of the slag and ash trouble was due to improper design and insufficient dimensions of the combustion chamber. Dust explosions were a bogey when the pipe system was well designed and looked after. He estimated the coal grinding and drying cost at 5*s.* or 5*s.* 6*d.* per ton, the figures including interest and depreciation. He had been able to test a number of plants, and had, at the pulverising plant of the Hammersmith Electricity Department, found an efficiency of 80 per cent. in a 72 hours' run with anthracite containing 18 per cent. of ash. In puddling furnaces in the north of England they had reduced the coal consumption in the ratio 25 : 12; he would not recommend powdered coal for Lancashire boilers, unless a kind of Dutch oven were built on in front, but it was suitable for water-tube boilers. The advantage of the powdering was that it gave the air an increased surface to act upon. There was no smoke at the Hammersmith plant, only a haze; the combustion chamber should be sufficiently large to leave room for a cold zone underneath the hot zone.

Mr. Robert Bruce said that powdered coal had a great future; unfortunately nobody would tell them the size of combustion chamber wanted per pound of coal; that capacity was a fundamental question for the locomotive. In reply to this question and to an appeal by the chairman, who asked also about brick arches and baffles as a protection against the direct flame, Mr. Frank Evans, of the Underfeed Stoker Company, stated that he did not consider powdered coal economical except in certain specific cases. The costs of the fuel preparation were enormous, the capital outlay was four or five times that for an ordinary boiler plant, and a very large area was required. Efficiencies, claimed in America, of 90 per cent. made him smile; with mechanically-driven boiler plants 78 per cent. was an average. Anthracite could be used without admixture of bituminous coal, if finely subdivided; there were miles of fine anthracite in South Wales, at present only utilised for briquetting. Mr. Andrew Forster then gave a few definite figures of the combustion chamber dimensions for oil; in Admiralty boilers they burnt from 12·5 lb. to 14·5 lb. of oil per hour, per cubic foot capacity of combustion chamber. The licking flames would not hurt the tubes, as some members seemed to fear.

Dr. Ormandy, in replying to the discussion, said with regard to this last point that the danger came in when a slight film of oil could settle on the tube wall from the feed-water. In conducting hundreds of 48 hours' boiler tests he had not exceeded an efficiency of 84 per cent. with economisers. The dust trouble was serious; people in Warrington were certainly not fastidious about the atmosphere, but they had refused to put up with the chimney dust.

Fuel Oils for Internal-Combustion Engines.

Mr. Harold Moore, M.Sc., confined himself in this second paper to fuels for heavy oil engine. Wood distillation products, he said, were too expensive. Peat oils might become very important; lignite distillation was much developed on the Continent and gave very suitable oils, also for cold-starting engines, but lignite tars would not play an important part as fuel in the near future. The world production of shale oils was only about $\frac{1}{100}$ of that of petroleum, so that for the present petroleum and coal tar remained the main sources of fuels suitable for heavy oil engines. In this country, 1,900,000 tons of coal tar were produced per year, and in addition 30,000 tons of oil-gas tar from the gas industry; the two figures together represented about 2 per cent. of the world's petroleum production. During last year the crude oil production had increased by 24 per cent., against a previous annual increase of 4 per cent. Most of that increase came from Mexico. Only a small portion of that oil was available for heavy engines; oils for motors, lubricants, illumination and chemical and medicinal purposes commanded higher prices and were pushed consequently. As the demand for heavy marine oil engines increased, the encroachment upon supplies previously allocated to other markets also increased. The only buyer whom the oil-engine user could outbid was the buyer of fuel oil for furnace firing.

A similar position existed in the coal tar industry. Hitherto only the creosote oil fraction had been used as engine fuel; that fraction made up 20 per cent. of the tar weight, and was claimed also by timber preservers. The residue of the distillation, pitch, Mr. Moore thought hardly likely to become an engine fuel. But engines could no doubt be built to work with the lighter varieties of raw tar, yielded by coke ovens and by vertical gas retorts. The heavy oil engines had been much improved of late, mainly as to reliability. They would have to be adapted to use heavier fuels; that would necessitate research on spraying and pulverising devices, perhaps also an increase in compression, and a diminution of the engine speed. Most of the new oils were asphaltic and apt to clog the valves; but a Diesel engine which would not take an asphaltic oil at 200 revolutions might do so at 150 revolutions. There was more need for modification of engine design than for chemical research. A colloidal fuel would be very valuable. The heavy raw tars contained much suspended carbon which the chemists had failed to separate from the tar. But 0·08 per cent. of minerals would spoil an engine in a week, and most oils contained 0·2 per cent. of ash. The building of engines capable of utilising heavier fuels was the great field for research.

Mr. P. W. Petter, opening the discussion, wished to secure the oil supply by laying down specifications for oils suitable for internal-combustion engines. The rate at which oil had been replacing coal for boilers in these days was alarming; legislation might have to interfere. As regards lower speeds he was afraid that marine engines were already too heavy. Dr. Ormandy, speaking next, did not want more legislation. The situation would adjust itself; as the coal prices dropped the few firms who held a monopoly in the distribution of oil would raise the oil prices again. Mr. A. Carmichael, of Messrs. Allen, Bedford, did not see either how slower speed could meet the increasing demand for mercantile oil engines. Mr. Pendred agreed that the engine should be adapted to the fuel and spoke also of the advantages of alcohol fuel, the objections to which had long since been overcome; Sir Charles Bedford had recently stated that alcohol could be obtained from rice straw, the pulp yielding paper. Dr. Ormandy remarked that the alcohol would be the by-product of the paper, not the other way round. But such industries were important, because aeroplanes could no longer be expected to carry their fuel across continents and oceans, and would have to rely on supplies from local stations. The advantage of alcohol was its very high latent heat of evaporation; that kept the piston cool and admitted of high compression.

Mr. Moore, in replying to the speakers, agreed that alcohol was essentially the fuel for a constant-volume engine working at high compression and speed. He also accepted the specialisation of engines for types of fuel. He had advocated low speed engines merely as a last resort to which we might be driven. The specification of fuels for internal-combustion engines was not difficult, and such specifications had been drawn up here and elsewhere. As regards asphaltic oils he added that, experimenting at Messrs. Crossley's works, they had quite recently found that not all the asphaltic oils were unsuitable fuels; the new Persian oil was not asphaltic, moreover. Statistics as to oil-boiler plants were not available, but he was informed that 14,000 oil burners had been put in use quite lately; many of these would soon be out of use again.

After Mr. Pendred had closed the discussion, Mr. Petter pleaded for the utilisation of the sun's rays, in the first instance also by promotion of agriculture, and of such products as the Nile sudds.

Automatic Stokers.

At a meeting in the Council Room on Friday morning, the 1st inst., the first subject dealt with was automatic stokers. The chairman, Mr. Daniel Adamson, called upon Mr. A. W. Bennis, to read a short communication to form a basis for discussion. In this Mr. Bennis stated that there were four main principles affecting thermal efficiency, to which subject the discussion was exclusively confined. The first of these was continuity of operation. There were no violent fluctuations in air supply, furnace temperature or fuel feed, such as were unavoidable with hand firing. The constant high furnace temperature gave a continuous maximum rate of heat transmission to the water, and, generally, it was possible to approach continuously ideal combustion conditions in the furnace. The second main principle was flexibility of operation, by which he meant that the mechanically-fired boiler possessed advantages with respect to its adaptability to change of conditions. Boilers could run for many hours on light load with the least possible drop from full load efficiency, and a sudden rise in load could be met by a correspondingly rapid increase in steam production. Where mechanical firing was combined with forced draught, and perhaps with hot-air supply, the element of flexibility was most marked. Ability to burn a wide range of fuels was also included under this head. The third main principle, Mr. Bennis continued, was maximum steam output per boiler, due to the higher rate of combustion with mechanical firing, especially with the addition of mechanical draught. It was thus possible to reduce the number of boilers needed for a given maximum load with a consequent reduction in the stand-by losses. He also pointed out that the average thermal efficiency of a plant might be improved by a judicious sacrifice in efficiency during momentary high loads. The fourth main principle was centralised boiler-house control. By this means the ultimate control of boiler-house conditions was vested in a scientific expert, under whose detailed directions the firemen worked; this system could be adequately exercised only in a machine-fired boiler-house.

With regard to the choice of the system of air supply, Mr. Bennis stated that natural draught was, in many cases, fully adequate to meet the load, but, with very large boiler units, it had to be supplemented by induced or forced draught, or both, in order to burn the required weight of fuel on the available grate area. Mr. Bennis then briefly referred to the characteristics of various types of stokers, and concluded by remarking that in order to determine the increase in thermal efficiency due to automatic stokers it was necessary to study operating results over a lengthy period. In the case of many of the largest electrical undertakings, he added, results had been ascertained over a period of many years, leaving no doubt as to the advantages of machine stoking.

At the conclusion of Mr. Bennis' note the chairman said the discussion would be confined to matters affecting thermal efficiency or to the adaptability of different types of stoker to various classes of boiler, and he then called upon Mr. Charles Erith to open the discussion. Mr. Erith said he had no criticisms to make, as the principles, as laid down by Mr. Bennis, were indisputable. Large modern power plants, he said, demanded large-unit boilers, and these had of necessity to be of the water-tube type. With the large units now becoming general, high over-all efficiencies were possible, and there were a number of stations with which he was acquainted using less than 20,000 B.Th.U's. per kilowatt-hour. Such economy, however, was only possible under good conditions, and was much better than was usually obtained in industrial plants. Forced draught, the speaker continued, was necessary with stokers of the underfeed type, and, in any case, mechanical control of the air supply was essential to obtain high efficiency. The working cost of the fans, he said, need not exceed 1 per cent., and the cost was returned many times over by the higher efficiency obtained. Referring to underfeed stokers, he said the great point was that the maximum theoretical temperature of combustion was obtained as the fire, being fed from below, formed its own coking arch. No other coking arch was required as the mixing of the air and gases was effected within the fuel and the heat was transferred to the tubes by direct radiation.

Mr. D. Brownlie, the next speaker, said that Mr. Bennis had not mentioned one advantage of

mechanical stokers, which, in the speaker's opinion, was the most important of all. He was referring to the elimination of the heavy labour of hand-stoking. On an average about six tons of coal were handled per day per man with hand firing, and in some cases as much as 10 tons had been moved. Nowadays it was difficult to find men willing to do such heavy work, and it was the right thing to do away with it if possible. He did not, however, agree that fluctuations were less with mechanical than with hand-firing. A point of considerable importance in connection with mechanical stokers, the speaker continued, was the cost of repairs, but it was difficult to get accurate figures. In a particular case, however, of an installation of nine Lancashire boilers fitted with sprinkler-type stokers the repairs had cost 259*l.* per annum, and the labour in connection with the repairs, 220*l.* The total item, in this case, amounted to about 2¼ per cent. of the coal bill. If steam jets were used they accounted for about 6 per cent. of the steam consumption, and consequently 6 per cent. of the coal used, and if the whole equipment cost 3,000*l.*, 6 per cent. interest on this, and 15 per cent. depreciation, accounted for another 2 per cent. of the annual expenditure. Ten per cent. of the saving due to mechanical stokers was thus wiped off, so that a fuel economy of 15 per cent. meant a saving of only 5 per cent. in expenditure. On the whole the speaker was in favour of mechanical stokers, but it was useless to disguise these facts. The trouble was that users did not pay sufficient attention to the upkeep of their plants, which were machines and needed attention as all machinery did.

Mr. H. C. Appleby, who followed, said the fact that machine stokers were so much appreciated by industrial users left no room for doubt that they were efficacious. There were certainly running expenses, as pointed out by Mr. Brownlie, but if more steam could be obtained and greater production resulted, users would be satisfied. With regard to fluctuations the speaker's experience, in connection with dyeing, was that these were much greater with hand firing than with machine stokers. He also referred to the quantity of steam used in steam jet blowers, and mentioned a case in which the quantity had been reduced from 8 per cent. to 3 per cent. by changing the nozzles. In that particular case arrangements had been made to change the nozzles regularly after working for a given number of hours.

The discussion was continued by Mr. V. R. Chadwick, who said he thought the kernel of Mr. Bennis' communication was scientific control. The speaker knew of a case of a Lancashire boiler measuring 30 ft. by 8 ft. and fitted with a mechanical stoker, which gave an evaporation of only 500 gallons per hour, whereas with proper scientific control it should give 800 gallons per hour. In support of his point as to the necessity of careful supervision the speaker said that it sometimes happened with mechanical stoker installations that the fire was all concentrated in the front of the grate and the back was left quite bare for a length of 18 in. or so. Continuing his remarks the speaker said that Mr. Bennis' paper appeared to assume that the coal used was always of the same class, but actually there was probably a greater range of fuel in this country than in any other. A mechanical stoker, when adjusted for one class of fuel, would give satisfactory results as long as that fuel was supplied, but, if the fuel were changed, the efficiency would be greatly reduced. During the war a number of breweries, which were employing mechanical strokers, had been offered large coal or coke which could not be used with the stokers. Consequently they had gone back to hand firing and many were doing better than before. With regard to underfeed stokers referred to by Mr. Erith, the speaker mentioned a difficulty he had experienced in burning a Staffordshire coal with high caking properties in stokers of this class. The coal, he said, formed into a cake which rose above the main fire, burnt out and dropped down, giving a low efficiency. The difference between underfeed and top-fired stokers he illustrated by striking two matches, one of which he held upright and the other in the inverted position. The former, which represented the underfeed stoker, burnt steadily and slowly while the latter burnt fiercely and was rapidly consumed. He thought it would be necessary to devise a stoker which might be described as a cross between the two types, as in the underfeed stoker, which was superior from the point of view of thermal efficiency, the rate of combustion was too slow.

The last speaker in the discussion, Captain S. C. Bullock, said he had experienced trouble with a mechanical stoker in endeavouring to burn a mixture of anthracite dust with bituminous coal dust containing some 25 per cent. to 30 per cent. of volatile matter. The fuel, however, caked too much unless the draught was excessive, and in that case it was carried up the chimney. He asked if it were possible efficiently to burn coal dust alone in any type of mechanical stoker.

No other member present wishing to take part in the discussion the chairman, before calling on Mr. Bennis to reply, remarked that mechanical firing had become of great importance in recent years. The engineer, he said, had to choose the right plant and see that it worked efficiently. By employing machines to do the stokers' work trouble due to the human element was avoided, but it was necessary to have a different class of man in charge. It was difficult to find a man of sufficient muscular strength to work at hand firing possessed of sufficient intelligence to understand the processes of combustion. More attention, he thought, must be given to the physical aspect of the problem. No machinery could take the place of human beings. It was only an assistant and got out of control unless proper attention was given to its working. We were inclined, he thought, to depend too much upon machinery and did not always take sufficient care of it. It was necessary not only to choose the right plant but also to put the right men in charge of it.

Mr. Bennis, in his reply, said that Mr. Erith had picked out a point which should have been referred to when he mentioned the mechanical control of air. It was not always necessary, Mr. Bennis pointed out, to use a large amount of air; the right quantity was required in the right place, which was through the fire and not elsewhere. The same remarks, he added, also applied to natural or induced draught, but the desired results were more easily achieved with forced draught than with the other systems. Mr. Brownlie, the speaker said, had raised some controversial questions, the replies to which would occupy too much time. It was certainly true that mechanical stokers reduced labour costs, but that had nothing to do with thermal efficiency. He agreed with Mr. Brownlie as to the necessity for keeping stokers in good condition, and said that many firms now kept their installations in better order than formerly. There were, however, numerous instances of neglect, and his firm had employed inspectors to visit plants and point out what repairs were necessary.

With regard to steam jets, he said that nearly all mechanical stokers used with internally-fired boilers employed such jets, and it was his practice to ask users to change the nozzles at least once a year. One speaker had mentioned that the steam consumption of jets could be kept at 3 per cent., and what was done in one case could also be done in others. Steam used in jets, however, was not all lost as it cooled the firebars and also produced a certain amount of water gas which was afterwards burnt and returned some heat to the boiler. He was convinced that the manufacturers in Lancashire and Yorkshire, for example, would not have installed mechanical stokers to the extent they had if Mr. Brownlie's contention were correct that they did not show a saving.

Mr. Chadwick, the speaker continued, had surmised that the paper assumed that the same class of fuel was always used, whereas it had been particularly mentioned that one of the main features of modern mechanical stokers was their suitability for any class of fuel. During the war, the speaker said, some firms had got a fuel, he could not call it coal, with a calorific value as low as 6,500 B.Th.U. per pound, and containing some 50 per cent. or 60 per cent. of ash. It was impossible to use it by hand-firing as it simply put the fires out, but by employing mechanical stokers some 18,000 tons had been burnt in one plant and steam had been kept up. In changing from such a fuel to one with a calorific value of say, 14,000 B.Th.U. per pound, it would, of course, be necessary to alter the rate of feed and the air supply; but either could be varied. Mechanical stokers could get the best results with any fuel if properly regulated; the necessary adjustments were provided and they should be used. It was true, as the chairman had remarked, that brains were not usually found with brawn. The scientific man did not much care for boiler-house work, but he was certainly wanted there.

Mr. Chadwick's experiment, the speaker said, resolved itself into a matter of air supply. If sufficient air were put into a stoker to burn the coal it could be burned provided that the air were supplied in the right place and at the proper pressure. The choice of an installation depended on many considerations, such as the class of fuel, the output of the plant and the rate of change of the load. No one could say that any particular type of stoker would be best for all possible conditions. With regard to the low evaporation mentioned by Mr. Chadwick, something was certainly wrong, but he could not say what it was from the particulars given. To Captain Bullock's query as to the burning of coal dust, the speaker replied that it certainly could be done by means of forced draught on a chain grate stoker or on an underfeed machine, but the air spaces of the chain grate would have to be small. Many installations were burning bituminous coal dust with no trouble at all, but anthracite dust was more difficult to deal with.

At the conclusion of Mr. Bennis' reply, he was thanked by the chairman who, after a brief interval, called upon Mr. W. H. Patchell to read his communication on the subject of air heaters for boiler plants.

AIR HEATERS.

In this Mr. Patchell pointed out that the supply of hot air to the furnaces of steam boilers was no novelty, and mentioned that in the 1854 edition of a book by Mr. C. Wye Williams, on the combustion of coal, reference was made to the use, in 1842, of vertical pipes at the back of a boiler to heat part of the air supplied above the grate; suction draught fans, he said, were also referred to. Air heaters had, of course, been very largely used in the mercantile marine in connection with the forced draught system originated by Messrs. James Howden and Co., of Glasgow. Detailed tests were not available, but that the heater had been commercially efficient was beyond question. The speaker had adopted air heaters many years ago—not for reasons of economy, but for smoke consumption. His installation had been supplied by Messrs. John Brown and Co., of Sheffield, whose own boilers were fitted with the Ellis and Eaves air heating system, which had effectively eliminated smoke.

He had found it difficult to get detailed data of similar boilers operated with and without air heaters from which the benefits of air heaters could be closely studied; but he had obtained the results of some overall tests of boilers fitted with air heaters from the Underfeed Stoker Company and the Stirling Boiler Company, as well as the results of some special trials of the ss. Saxonia fitted with the Howden system of forced draught and air heating. Further tests on a Belleville boiler fitted with superheater, "Thermix" fan and air heater were also available through the courtesy of Mr. S. Utting, and he, the speaker, had dissected and analysed the whole of the data as far as possible. The results of this analysis are given in the table printed on page 93. Mr. Patchell explained that the excess air had been calculated from Bunte's formula, assuming 18·9 per cent. CO_2 would be obtained with no excess air, and the figures were therefore only approximate. The air necessary for combustion, from which the extra efficiency had been calculated, could also only be obtained approximately. The extra efficiency, Mr. Patchell explained, only took account of the heat units returned to the furnace with the air.

A point worth noting in the table was that when the air supply was cut down to a minimum the extra efficiency, due to the air heater, was less than when a large excess of air was admitted. With regard to the effect of the hot air on the grate or stoker, the speaker said he thought that retort-type stokers, in which the grates were thickly covered, could be safely operated with a hotter air supply than chain-

grate stokers where the fuel fed was thin. The character of the fuel, however, had to be carefully considered, and there might be more anxiety as to the maintenance of the refractory materials than of the boiler itself. The removal of dust from air heaters, Mr. Patchell said, was a matter to which careful attention must be given. In conclusion, he hoped his remarks might be the means of obtaining better records of tests, and added that although the extra efficiencies shown by his analysis were certainly not sufficient to encourage the purchase of air heaters, it was a fact that they had given great satisfaction, and that there was an overall commercial advantage in using them.

The first contribution to the discussion was a written communication sent in by Mr. David Wilson, and brief extracts from this were read by the chairman. Mr. Wilson stated that there was little evidence that air heaters, in lieu of economisers, would be a success from the thermal efficiency point of view. The writer had made tests on two identical boilers, one fitted with a water economiser and the other with an air heater. The boiler had a heating surface of 6,295 sq. ft., while the heating surfaces of the economiser and air heater were 2,400 sq. ft. and 3,132 sq. ft., respectively. The results numerous concomitant advantages of which he mentioned, immediate response to overloads, reduction in smoke and soot production, and other points. The cost of an air heater and fan would be considerably less than that of a complete water economiser, and there was no danger of explosion of the former. In conclusion, he expressed the opinion that preheating the air for combustion in order to improve furnace conditions, should have the first claim on the heat contained in the waste gases.

Mr. A. W. Bennis, the next speaker, referred to the difficulty of obtaining accurate data on air heaters, and said he was anxious to get at the truth of the matter, as he sometimes received inquiries as to the desirability of installing air heaters and did not know what to advise. He inquired if Mr. Patchell had any data as to the cost of fire-bars when pre-heated air was used, and asked to what temperatures it was safe to go with ordinary bars. To the latter inquiry Mr. Patchell immediately replied that he thought Mr. Bennis would be better informed on that point than he, Mr. Patchell, was.

Mr. S. E. Fedden, who followed, remarked that air heaters came into and went out of use, but the water economiser was firmly established. With regard to the smoke reduction at Messrs. J. Brown There was a tendency to omit economisers on account of the highly sustained efficiency of modern boilers, and in power stations in which expanded steam was used for feed heating there was no inducement to employ them. In such cases an air heater might be used to recover some of the heat instead of the economiser, but he was in favour of the latter. The heat recovery claimed by Mr. Patchell for air heaters was very small, but, with the present high price of coal, small economies had to be considered. It might be possible to employ an air heater at the rear of the water economiser, but the speaker doubted if the heat recovered would compensate for the extra power absorbed by the fans. The air heater would, of course, recover more heat if placed between the boiler and the economiser, but it would do so mainly at the expense of the heat recovered by the economiser. In conclusion, he remarked that in modern power stations it was quite easy to obtain perfect combustion with cold air, so that the question of employing an air heater depended entirely on the heat units it returned to the system.

The next speaker, Mr. S. Utting, said he had been somewhat surprised at the use made of the test results he had supplied to Mr. Patchell. He

TESTS OF AIR HEATERS.

	Date.	Hours Duration.	Place.	Type of Boiler.	Heating Surface of Boiler.	Grate Area.	Type of Stoker.	Type of Air Heater.	Heating Surface of Air Heater.	Pounds of Coal per Square Foot of Grate Area per Hour.	Coal Burnt per Hour.	Ratio of Air Heating Surface to Coal Burnt per Hour.	Temp. of Gases.		Temp. of Air		Rise in Temperature of Air.	Excess Air over that Necessary.	Extra Efficiency* of Boiler Directly due to Air Heater.	Efficiency of Boiler and Air Heater.	Efficiency of Air Heater.
													Leaving Boiler.	Leaving Heater.	Entering Air Heater.	Entering Furnace.					
					sq. ft.	sq. ft.			sq. ft.		lb.		deg. F.	deg. F.	deg. F.	deg. F.	deg. F.	per c.	per c.	per c.	per c.
1	4·8·98	7	Lambeth	Brown's Marine	975	34·0	Hand-fired induced draught	Ellis and Eaves	900	41·0	1,405	0·64	—	460	118	295	177	110	—	74·0	—
2	5·8·98	4	Lambeth	,, ,,	975	34·0	,, ,,	,, ,,	900	50·0	1,702	0·53	—	442	112	303	191	117	—	60·0	—
3	28·1·14	4	Portsmouth Dockyard	Stirling ..	3,660	65·7	Underfeed travelling	Usco ..	1,800	30·5	2,000	0·90	526	374	68	197	129	28	3·1	85·3†	79
4	29·1·14	4	Portsmouth Dockyard	Stirling ..	3,660	65·7	,, ,,	Usco ..	1,800	33·0	2,150	0·84	564	385	71	202	131	61	4·0	83·6†	69
5	26·9·13	4	Hammersmith ..	Stirling ..	6,203	99·0	,, ,,	Usco ..	2,204	35·5	3,528	0·62	588	383	92	247	155	47	4·2	83·3†	71
6	16·1·12	6	Devonport Dockyard	Woodeson	4,100	77·0	Class "E" underfeed	Usco ..	2,378	31·0	2,414	0·98	525	—	79	225	146	54	4·2	82·1†	—
7	17·1·12	4	Devonport Dockyard	Woodeson	4,100	77·0	,, ,,	Usco ..	2,378	42·5	3,275	0·73	591	402	77	230	153	36	3·9	80·5†	76
8	18·1·12	6	Devonport Dockyard	Woodeson	4,100	77·0	,, ,,	Usco ..	2,378	31·0	2,400	0·99	584	—	88	259	171	69	5·4	80·4†	—
9	19·1·12	4	Devonport Dockyard	Woodeson	4,100	77·0	,, ,,	Usco ..	2,378	41·0	3,175	0·75	648	—	88	272	184	54	5·3	79·5†	—
10	5·2·01	13	S.S. Saxonia (average of 9 boilers)	Marine ..	2,867	63·3	Hand-fired forced draught	Howden	766	20·5	1,303	0·65	491	306	85	185	100	106	—	82·3	—
11	21·1·21	8	Michel and Chappat Clichy	Belleville ..	825	38·5	,, ,,	Thermix	755	15·0	585	1·29	572/608	428/471	55	194	138	89	4·7	69·2†	—

* These "Extra efficiencies" only take into account the thermal units returned to the furnace with the air.

† These efficiencies include superheaters.

of these tests showed that 7·22 per cent. of the total heat was absorbed by the water economiser and only 4·37 per cent. by the air heater. Mr. Wilson, however, pointed out that there were other considerations than thermal efficiency which might justify the employment of air heaters in preference to economisers as, for instance, in cases where turbine exhaust was partially used for water heating.

Mr. W. H. Owen, who read his remarks, said that the Howden system of air heating had been applied to about 24,000,000 h.p. in marine installations with complete success. Few tests had been made on land boilers, but comparative tests carried out by Messrs. D. Rowan and Co., of Glasgow, on their own works boiler of the marine type, which tests extended over a week in each case, showed a 15 per cent. saving in coal in favour of the air heater. It was, he thought, surprising that more use of air heating had not been made in land power plants, although 76 installations of Howden's hot-air forced draught had been carried out on land. Engineers were apparently satisfied that if the temperature of the waste gases were reduced to a reasonably low level by the use of economisers, no further improvement was to be expected, but the speaker said he regarded combustion as the essential process in steam raising, and thought this should be rendered as perfect as possible. It was mainly in the secondary stage of combustion that losses occurred, and these could be materially reduced if the secondary air were preheated. There was much to be said for a system which tended to perfect the fundamental process of combustion, and, at the same time, there were and Co.'s works, mentioned by Mr. Patchell, the speaker thought that cold air would have been equally effective, and he did not think the economies obtained by air heaters were sufficient to justify their use. He (the speaker) had installed air heaters some 20 years ago and had been able to increase the evaporation of a particular boiler from 11,000 lb. to 14,000 lb. per hour. No trouble had been experienced with the fire-bars since these were protected by steam jets. In the case of a Stirling boiler, however, to which the same system had been applied, trouble had been experienced with the rear bank of tubes, which were used for feed heating. To avoid this he had put in a live steam feed heater, and afterwards an economiser, but the air heater wore out and corroded away, and was not replaced. Another attempt was made later with different stokers, and in this case the furnace temperatures were too high, so that the bars melted. The result of his own experience was that he would rather be without air heaters, but he was willing to learn from the experience of others.

Mr. Charles Erith, who continued the discussion, said the problem of air heating as a possible economy in power stations differed materially from its use at sea. He did not think Mr. Patchell's tests could be taken seriously. One of them showed 106 per cent. excess air with a thermal efficiency of 82·3 per cent., and most of them were of short duration. At sea it was out of the question to use the type of economiser commonly employed on land, and with regard to air heating in land power stations he thought Mr. Fedden's experience was conclusive. thought the column in the table giving the extra efficiency due to air heating was liable to misinterpretation. He assumed that it represented the heat units returned to the boiler, and that it was based on the heat units in the coal as fired. Mr. Patchell here remarked that that was the case. Mr. Utting, continuing, said he thought that Mr. Fedden's experiences were similar to those in connection with many other engineering developments. Superheaters, he reminded the members, had been introduced and abandoned, but were now in general use; he thought that the development of air heaters would be similar. On the question of economisers *versus* air heaters, he pointed out that the advantage would lie with that method which gave the lower capital and running costs. It might be possible, in some cases, to reduce the size of the economiser, in order to lessen the capital cost, and recover the balance of the heat by air heaters, and in some installations the heated air could be used for other purposes in the works instead of being supplied to the furnace. At a paper mill in France, the speaker stated, half the heated air was used in the furnaces and the other half for purposes for which live steam would otherwise have been employed. In power stations there was certainly a tendency to dispense with economisers, and he thought that, owing to the higher pressures likely to be employed in the future, it would be necessary either to employ steel tubes instead of cast iron tubes for economisers or to replace them by air heaters.

Mr. G. A. Tansley referred to some tests he had made on two Lancashire boilers fitted with Meldrum

furnaces, one of which had steam jets without an air heater, while the other had an air heater without jets. The jets took about 7 per cent. of the steam, but the boiler on which they were fitted supplied more steam to the works than the other. The fires with the steam-jet furnace were well open, and the CO_2 recorded was about 14 per cent. with no CO, whereas with the hot-air furnace the fires required constant cleaning and 2 per cent. of CO was present in the flue gas. Although the hot-air furnace saved the 7 per cent. of steam supplied to the jets, the advantage was on the side of the steam-jet furnace, without the air heater, to the extent of about 1 per cent.

The last speaker, Mr. G. T. Gillespy, referred to the difficulty experienced by marine engineers of keeping steam in modern high-pressure boilers when supplied with inferior fuel, and said that if air heaters had any advantages from that point of view marine engineers would certainly find them valuable.

The Chairman, in calling on Mr. Patchell to reply to the discussion, mentioned that he understood from Mr. F. H. Trevithick that he had obtained an advantage of about 5 per cent. with air heating on locomotives on the Egyptian State Railways, but that Mr. Trevithick was of the opinion that, for locomotives, air heating did not justify the trouble and outlay involved.

Mr. Patchell, in his reply, first referred to water economisers, and said that with large turbo-generator sets and steam-driven auxiliaries, a certain amount of steam was available for water heating. With large boilers there was not much for economisers to do, and they were consequently cut out of the equipment, but as the price of coal went up it became necessary to consider further economies. For high pressures steel-tube economisers would be necessary, and it would pay to instal them, although that would not have been the case a few years ago. Air heaters, Mr. Patchell continued, had been sold on their merits as an economical proposition, but there seemed to be no real figures as to their performances. With regard to his analysis of such figures as he had been able to obtain, he admitted that there were numerous differences which affected the results. The coal, for instance, was not always the same, and if the ash were fusible the combustion might be worse when hot air was supplied under the grate. There were also difficulties in connection with the estimation of excess air. He had, however, obtained the most reliable figures he could and analysed them as carefully as the nature of the data permitted. With regard to the Lancashire boiler trials referred to by Mr. Tansley, he thought there must be some difference either in the coal or the draught, and to Mr. Gillespy's query he regretted that he could not reply as he had no marine experience.

After the Chairman had thanked Mr. Patchell for his communication the meeting terminated.

On Friday, July 1, the Conference held a meeting at 10.30 a.m. in the Committee Room of the Institution, to hear and discuss the following contributions, namely, "Feed Heating and Economisers," by Mr. C. E. Stromeyer, O.B.E., Member, and "The Indicator as an Aid to Economy," by Professor W. E. Dalby, F.R.S., Member of Council. This meeting was presided over by Dr. T. E. Stanton, C.B.E., F.R.S., Member of Council.

In introducing the subject, Mr. C. E. Stromeyer said that in air heating there was theoretically no limit to the temperature that could be obtained, though this must not be high enough to burn the fire-bars. On the other hand, the temperature of the water in a feed heater could not be raised above that of the water in the boiler. Moreover, whilst cold air could be introduced directly into an air heater, cold water could not be passed into an economiser, since if the temperature of any part of the latter were less than 120 deg. F. moisture charged with acids from the waste gases would be deposited on the cool part and corrosion would be very rapid. At the most the temperature of the feed was raised in an economiser by 200 deg. F., the consequent reduction in the waste gas temperature being 300 deg. to 400 deg. F., and the final temperature of these gases must not be less than 100 deg. F. if excessive corrosion were to be avoided. The Manchester Steam Users' Association required 4½-in. economiser pipes to be specially examined if their external diameter was reduced by corrosion to less than 4¼ in. In order to prevent cold water entering the economiser, it was sometimes preheated by being mixed with a return flow from the hot end of the economiser. In other cases the water was first passed through a feed heater. Live steam feed-heating had been advocated on theoretical grounds, but in practice its value had yet to be proved. He suggested that "vapour compression" evaporators might often prove advantageous. In these a pump drew off vapour from one side of the evaporator and delivered it under pressure, and at a consequently higher temperature, to the other side. Here it condensed on the tubes, delivering up its heat to the cold side and promoting ebullition there. In this way it was claimed that as much as 60 lb. of distilled water were obtained per 1 lb. of coal burnt, and the return theoretically possible was much greater than this. The process was somewhat handicapped by the inefficiency of the engine and compressor. In the practical operation of economisers scale caused much more trouble than in boilers. In the latter case there was a rapid fall of temperature between the furnace and the discharge end of the tubes or flues. If scale were deposited it meant in the main merely that less heat was transferred during the early portion of the transit of the gases and more during the later portion, and hence the final temperature of the waste gases was not materially altered. With economisers and feed heaters, however, the temperature gradient from end to end was small. Hence if scale or grease were deposited on the tubes the heat transmission was greatly reduced. He thought that Messrs. Green's system of scraping the outsides of the tubes was correct in principle. It would appear that both feed heaters and economisers should be operated on the counter-current system, the cold feed entering at the end at which the heating fluid was discharged. The plan was, however, not in favour apparently because of a terrific explosion in an economiser thus operated. This explosion had, however, nothing to do with the principle, but to bad design, owing to which steam formed in certain tubes and gave rise to a water hammer which fractured the pipes and produced a terrific explosion. In some counter-current feed heaters there had been serious corrosion, but here again the principle was not at fault, since the corrosion was due to the very slow motion of the fluids, owing to which air settled on the heating surface and was not, as in the case of boilers, carried away by the rapid circulation set up. In another case the slow movements of the water caused a heavy deposit on the pipes of crystalline scale, which had to be cleaned off by chemical means. In general the failure of an economiser tube was not dangerous. Such explosions as had occurred were due to mistakes in operation. If the feed were shut off, whilst the waste gases were still allowed to pass, steam was produced inside the tubes and led to water hammer, which knocked out the bottom box of the economiser.

The discussion was opened by Mr. Druitt Halpin, who said he was a strong believer in hot feed. In some very careful comparative trials at which he had been present some thirty years ago, the substitution of hot feed for cold caused an improvement of 17 per cent. in the rate of evaporation; and in another set of trials made some years later with boilers fitted with chain grate stokers the substitution of hot feed for cold raised the rate of evaporation from some 10,000 lb. to 11,000 lb. of steam per ton to 17,500 lb. of steam. Hot feed also eliminated trouble from the precipitation of lime. If this came down in the boiler, it was "baked on" and difficult to remove, but in the feed heater the temperature was too low to bake the scale on.

Mr. Tansley said that some tests he had made with air heating some years ago showed no gain in economy as the hot air coked the fires on to the grates, so that they had to be cleaned twice as often as before, and the proportion of CO_2 in the waste gases was also diminished. As for the counter-current system of operating economisers he believed it to be dangerous, and though theoretically the plan might show an economy on paper this was not realised in some very extensive tests made in America, at which the speaker was present. Economiser tubes should be scraped continuously, as tests showed that if merely scraped for ½ hour every 12 hours, there was a loss of efficiency.

Mr. Garnett, who followed, said that he thought that it was insufficient to demand the removal of economiser tubes when the external diameter was reduced from 4¼ in. to 4¼ in., since corrosion might be internal as well as external, particularly when very soft water, such as that of Loch Katrin, was used for the feed.

Dr. Stanton, before calling on the author for his reply, recalled an experiment of Osborne Reynolds, in which water was passed through a tube at various velocities whilst the tube was maintained at a constant temperature. In these experiments the rise of the water temperature was almost independent of the water speed, so that the rate of heat transmission appeared to be directly proportional to the velocity. In practice the velocity of flow was limited by the fact that the power expended in pumping rose rapidly as the speed increased. He presumed that the necessity of getting draught, limited the temperature to which it was profitable to reduce the waste gases.

In reply, Mr. Stromeyer suggested that the failure of air heating to which Mr. Tansley had referred was due to the arrangements being unsuitable with the particular coal used. Howden's system of air heating had been very satisfactory. Referring to the chairman's remarks, he said that the production of draught by natural means absorbed about 15 per cent. of the heat generated in the boiler, but on the other hand the cost of generating draught by fans was also considerable. Dr. Nicolson had invented a boiler based on Osborne Reynolds observations, in which the hot gases were passed over the heating surfaces at a high velocity. The heat transmission was excellent, but the result was disastrous to the boiler, as the plates became nearly red hot on the gas side. In feed heaters, however, temperatures were lower and the use of high speed would not suffer from the same drawback, but all the same such speeds had to be paid for. With respect to economisers, graphitic corrosion occurred mainly at the top of the pipes and internal corrosion at the bottom. The former was easily detected by inspectors, and the owner could be warned. In view of the high pressures now coming into use he did not like cast-iron economiser pipes, as the material was not thoroughly reliable. In some cases tubes began to fail within a week, and he would therefore, with high pressures, prefer steel tubes, although as such tubes were thin, pitting might, in the absence of precautions, be very severe.

The Use of the Indicator.

Professor Dalby's paper on "The Indicator as an Aid to Economy," was, in the absence of the author, read by Professor Michell. In this paper the author said that the indicator was as important in investigating valve setting as in indicating the power. In the case of internal-combustion engines a fraction of a second's difference in the timing of the ignition made a large difference in the power produced; and the indicator made it possible to get the best valve setting without a long process of "tuning up" on the brake. In the case of internal-combustion engines where changes of pressure were very rapid, the optical indicator was the most satisfactory, and he had a preference for the disc type, while experience showed that it was best to use two mirrors, one moving with changes of pressure and the other with piston displacements. The objection made to the disc indicator, viz., that it became hot, thus altering the pressure scale, was of slight importance, since the object of the diagram was rather to ascertain what went on in the engine cylinder than to determine the horse-power. It worked well even with engines running at 2,000 r.p.m.

The discussion was opened by Mr. Druitt Halpin, who advocated the use of integrating indicators in cases where it was desired to determine the power of the engine rather than the accuracy of the valve setting.

Professor Burstall, who spoke next, said that in conjunction with Dr. Watson he had made many

experiments with disc indicators, which did suffer from the serious defect of changing scale; and, moreover, there were hysteresis effects, and changes of zero. He preferred, therefore, the piston type in spite of the drawbacks due to piston friction and inertia, and to the cooling of the cylinder. The spring, however, could be protected, and once calibrated remained reliable for all time, unless greatly overstressed in use. He had constructed one of these instruments in which the periodic time of the piston and spring was $\frac{1}{1450}$ second. This worked satisfactorily on an engine running at 2,500 r.p.m., although there were oscillations in the expansion line. Moreover, with this type a light spring diagram could be taken showing the fluctuations in the induction pipe and manifold. These diagrams had proved that in certain cases impulsive waves of pressure occurred here, owing to which one cylinder took more than its fair share of petrol. He had taken from a petrol engine simultaneous diagrams with a pencil indicator and the optical type. The former gave good-looking diagrams, but showed maximum pressures as much as 100 lb. too high, and that type of indicator was in fact quite untrustworthy at speeds in excess of 500 r.p.m.

Mr. Hodgson said that much care was necessary to keep a piston indicator clean, as the least dirt caused friction. Whilst, therefore, for scientific purposes, he considered the piston indicator essential for workshop use, the advantage lay with the disc type. He suggested, that a measurement of the piston friction of an indicator at low pressures afforded no information as to the probable friction when in use. For workshop purposes a more convenient type of indicator than the optical was needed, even at some expense of accuracy.

Mr. Okehill said that on stationary internal-combustion engines he had found the pencil indicator satisfactory up to 300 r.p.m. In his works practice the indicator was checked by comparing the indicated with the brake horse-power. If the mechanical efficiency curve came out at less than 80 per cent. it was assumed that something was wrong with the indicator. He suggested that there was no satisfactory proof that the optical was more accurate than the pencil indicator.

In reply, Professor Michell said that in his experience, even at low speeds the accuracy of a diagram taken with a pencil indicator depended largely on the observer. Nevertheless, surprisingly good results could be obtained with it up to speeds of 250 r.p.m. to 300 r.p.m., but beyond that limit the optical type became of importance. He held no brief for the disc type, though he believed that the friction with the piston type was very serious, and in some of Professor Burstall's diagrams a series of flats appeared on the compression line which could hardly be attributed to anything in the engine cylinder. As to the alteration of the scale of the disc type with temperature, Professor Watson had concluded that this might amount to 2½ per cent. at most, which was not a large figure. With pencil indicators it was easy to make as large an error as this in merely planimetering the cards. He had not found any hysteresis or alteration in the strength of the springs. In one case the indicator had been left in position on a Diesel for two years, and then new diagrams taken, and these showed no change in the strength of the spring. Owing to the small motion of the disc there was no error due to throttling in the port between the cylinder and the indicator. The disc type was quite as good for light spring diagrams as the piston type, indeed it was possibly the better of the two for this particular purpose.

This concluded the summer meeting of the Institution of Mechanical Engineers, a meeting which, it was generally agreed, was a complete success.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—The following Council has been elected for the session 1921–22.—President, Sir William Joseph Noble, Bart. Vice-Presidents: Messrs. Charles Waldie Cairns, Andrew Laing, Clarence Dalrymple Smith and Robert Wallis. Ordinary Members of Council: Messrs. Benjamin Chapman Browne, Engineer-Commander Charles John Hawkes, R.N. (retired), Robert Hinchliffe, Hugh Laing, and Dr. John Edward Stead. Honorary treasurer, Mr. Robert Hope Winstanley.

THE RING TOOL.

FOR use in automatic lathes the ring tool, or circular form tool, is in almost universal use for producing the outside contour of the piece being turned, and is in very common use for parting-off as well. Its only serious disadvantage is that it cannot always have side clearance at all points, so that where side clearance is of importance, as in parting-off, it is frequently the best practice to employ a straight tool.

Fig. 1.

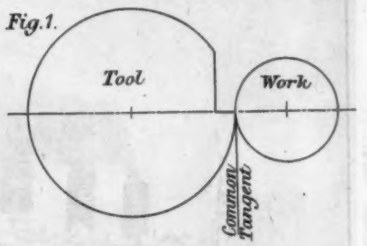


Fig. 2.

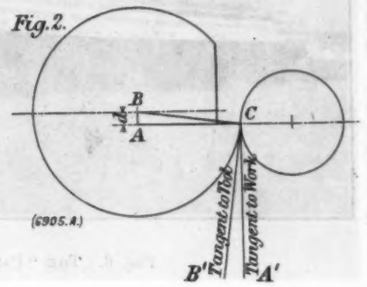


Fig. 3.

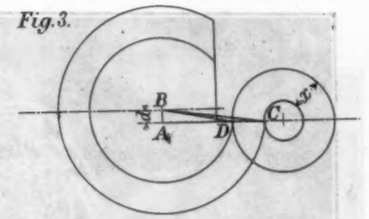


Fig. 4.

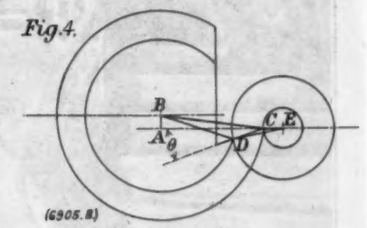
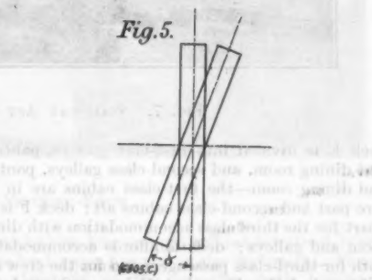


Fig. 5.



However, the amount of rubbing caused by lack of side clearance in the ring tool is frequently very small, and may sometimes be entirely obviated by turning the whole tool into a plane at an angle (equal to the clearance angle) with the vertical. If this can be done, or if the question of side clearance does not enter, then the ring tool may be made to have the same clearance angles and top rake as a straight tool, as will be explained below. The practice of using flat-topped (*i.e.*, no rake) ring tools has usually nothing to recommend it, and is frequently the cause of poor finish, slow work and quick wear of tool.

The following demonstrations enable the designer to allow for the correction of diameters for clearance, as is now commonly done, and for top rake, which is seldom used at present largely for the reason that the correct way of calculating the diameters is not properly understood. Certainly in many cases top rake can be put on a tool made without appropriate allowance, and it will still be just possible to produce work to gauge, but the effect has been to reduce the "tolerance" and so make an increase of scrap work inevitable.

(1) The first necessity in using a ring tool is to obtain a clearance angle at the cutting point. If the centre of the tool is "on centre" with the work (*i.e.*, if centre of tool, point of contact of cutting edge with work, and centre of work are in one straight line), as in Fig. 1, there will be no clearance, as the tangents to the work and to the tool coincide, and, therefore, the portions of the tool and of the work near to the cutting edge (which lie along the tangent at that point) will also coincide and cause rubbing on one another, with the result that the work will be ridged and the tool edge burnt off.

To overcome this the centre of the tool is raised by an amount d (if the tool is on the back slide it is lowered by this amount). In Fig. 2, A B is the distance d and $A^1 C B^1$ is the angle of clearance which we wish to make n degrees. Then from the figure it is plain that the angle $A^1 C B^1$ is the same as the angle A B C. Thus if A B C is n degrees we have $d = R \sin n°$, where R is the radius of the tool.

For a 2-in. diameter ring tool R = 1, and if $n = 5$ we get 0·08715 in. as the value of d. If d is made an eighth of an inch, the clearance works out at 7° 11′. For the remainder of this paper we shall continue to take for example a 2-in. ring tool (outside diameter) and $d = \frac{1}{8}$ in.

(2) Now suppose that the above tool is cutting two different diameters on the work, as in Fig. 3. Then if R_1 is the larger radius of the tool and R_2 the smaller, we require to find R_2 to give the required difference x on the work.

Then referring to Fig. 3, where D C = x it is clear that $A C^2 = R_1^2 - d^2$, and

$$A D = \sqrt{R_1^2 - d^2} - x$$

$$\therefore \quad B D^2 = R_2^2 = d^2 + (\sqrt{R_1^2 - d^2} - x)^2$$

or

$$R_2 = \sqrt{R_1^2 + x^2 - 2x\sqrt{R_1^2 - d^2}}$$

Taking the smaller diameter of the work as ¾ in. and the larger one as 1 in., we find that $R_2 = 0{\cdot}69115$, which is greater than $(R_1 - x)$ by 0·00365. The diameter is therefore 0·00730 in. greater.

(3) If, now, in addition to clearance we grind the tool so that it cuts with a top rake θ, as in Fig. 4, R_2, the smaller radius of the cutting tool, will have a different value from that given above and, moreover, its value will depend on R_1 and R_4, the larger and smaller radii of the work as well as on their difference, or, in other words, the tool will only be correct for one particular piece of work and not for any piece of work having the same form and difference of diameters as in the case of the flat-topped tool.

To find R_2 in this case we must first find C D, which makes the angle θ with A C. C D is found from the triangle C E D, for the sides C E and E D are known, being R_4 and R_3, respectively, and the angle D C E is $\pi - \theta$. Thus

$$C D = \sqrt{R_4^2 \cos^2\theta + R_3^2 - R_4^2} - R_4 \cos\theta.$$

Having found C D, which, with the dimensions previously used works out as 0·31419 in. for $\theta = 20$ deg., we now have to find R_2 from the triangle B C D, for the angle B C A was previously worked out as $\sin^{-1}\frac{d}{R_1}$ or 7° 11′, and consequently the angle B C D is known, and as the two sides B C (= R_1) and C D are known, the remaining side

$$B D = R_2 = \sqrt{R_1^2 + C D^2 - 2 R_1 C D \cos B C D}.$$

For the case we have been considering this amounts to 0·73468 in., or the diameter would be 1·46936 in., which is less by 0·03064 than twice $(R_1 - R_4)$.

The example chosen shows very plainly that the

correction of diameters may amount to large proportions, and is quite different when different top rakes are used.

It should be noted that at the points C and D both clearance and rake are different. Thus at D, where cutting is taking place at maximum speed, the top rake is not the nominal rake θ but is $\theta - \phi$, where $\sin \phi = \frac{C D \sin \theta}{R_3}$, or in the case we have taken as example not 20 deg. but only 7° 35′, while the clearance has increased to 18° 27′.

(4) If the tool is canted to obtain a clearance a deg., as in Fig. 5, then each width of the tool must be multiplied by $\cos a$.

The above article completes the geometry of the ring tool, and will be found useful for reference in drawing offices using these tools extensively. The most convenient form for drawing office use is that of a table, and while a general table showing the corrections for rake would be a bulky one to compile, a more limited list applying to the work of any particular factory would be compact and of the utmost value.

THE FRENCH TRANSATLANTIC LINER "PARIS."

THE Société Anonyme des Chantier et Ateliers de St. Nazaire, whose works we described in detail in a former issue (see ENGINEERING, vol. xc., page 847), have recently completed and handed over to the owners, the Compagnie Générale Transatlantique, the steamship "Paris," which forms a valuable addition to that company's North American Line. Had it not been for the war, the Paris would have been ready for service much earlier. She has now completed her first run to and from the United States. She started from Havre on June 15 and returned to that French port in the evening of the 1st inst. For the first outward trip it had been decided beforehand not to exceed in any great degree a speed of 20 knots, and the average speed from the Havre lightship to Ambrose Channel was 20·2 knots. On the return journey more latitude was given the captain in this respect, and notwithstanding a greater load than for the outward trip, the average speed during the return trip, also between Ambrose Channel and the Havre lightship was 22·2 knots. The oil fuel consumption during the return trip exceeded that during the outward trip by about 300 tons only. For the whole of this first run, the steam pressure remained perfectly regular, and all the machinery worked most satisfactorily. The passengers all agreed that the ship is a most steady one. The "Paris" starts again for the United States to-morrow, the 16th inst.

Our illustrations, Figs. 1 to 5 on Plate VI, are a longitudinal section of the "Paris," and the plans of the decks A, B and C. We reproduce a view of the "Paris" leaving St. Nazaire in Fig. 6, on this page.

The principal dimensions and characteristic features of the ship are as follows:—

	M.	Ft.	In.
Length over all	233·03 =	764	6
Length between perpendiculars	224·15 =	735	4
Breadth moulded	26·00 =	85	4
Depth of hold, from deck C to top of keel	20·75 =	68	2
Draught loaded	9·50 =	31	2
Displacement at this draught	36,700 tons		
Capacity of cargo hold	...3,500 cm. = 123,600 c.ft.		
Tons burden...	10,093 tons.		

The deck from which the depth of 20·75 m. is reckoned has above it two decks, B and A, the former being 2·75 m. (9 ft.) above C, and having a large deckhouse containing a number of saloons, and A 4·20 m. (13 ft. 9 in.) above B, so that the top of the deck-house gives a total height of 27·7 m. (90 ft. 11 in.) above the keel of the ship.

The ship has nine decks, deck A, the top deck carrying the boats; deck B, where are the first-class saloons and promenades; deck C, in the central part of which are the cabins de luxe, the aft portion being set apart for the second-class promenade and a part of the second-class accommodation; deck D, forming aft the top of the poop, and being the first entire deck from the stem to stern; on this deck are the first class dining saloon, the main part of the first-class cabins amidships, and aft are located second-class cabins; deck E is divided into first-class galleys, pantries, and dining room, and second-class galleys, pantries and dining room—the first-class cabins are in the fore part and second-class cabins aft; deck F is set apart for the third class accommodation with dining room and galleys; deck G affords accommodation both for third-class passengers and for the crew and personnel of the ship; deck H has accommodation in the fore part for third-class passengers, whi'st aft are galleys and cold stores. There is besides both fore and aft an orlop deck for luggage, postal packets and cargo.

Great care has been given to the designing of the ship. The deck C being, as stated, 20·75 m., above the keel insures great stiffness to the girder it forms with the hull. The material used is high tensile steel, which is used also for all members between the C D and D E decks, and is hydraulic riveted with cup-head rivets. The deck B ends in front of the deck-house, at 44 m. (144 ft. 4 in.) from the stem. The deck A ends 12 m. (39 ft. 4 in.) further aft. The promenade deck and the bridge are thus protected by a series of back-sets forming breakwaters which insure safety to the passengers and navigating officers in heavy weather when the sea breaks over the fore-deck. Astern, the deck shelters are also staged and are lengthened out progressively so as to form promenades for first and second-class passengers and for the crew, insuring at the same time the symmetry of the upper works. In fine weather the third-class promenade is forward of the deck C, but this class has also a covered promenade forward of the deck D. The first-class promenade, on deck B, is widened out on both sides to the extent of 0·5 m. (19 in.), beyond the outside plating. There being no falling-home of the sides the width of the first-class promenade deck is thus 27 m. (88 ft. 7 in.), which has rendered it possible to make the accommodation on this deck of ample dimensions whilst giving the passenger promenade a width of 6 m. (19 ft. 8 in.) on each side.

THE TRANSATLANTIC LINER "PARIS."

CONSTRUCTED BY THE CHANTIER ET ATELIERS DE ST. NAZAIRE.

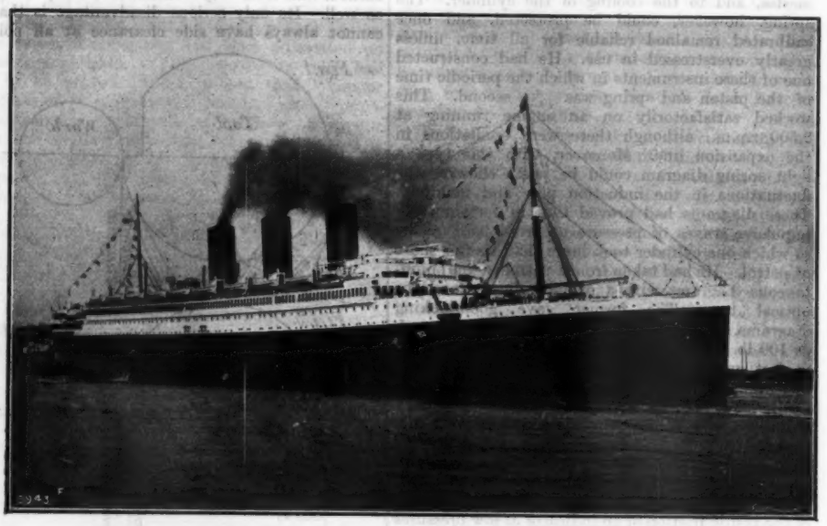


FIG. 6. THE "PARIS" LEAVING ST. NAZAIRE.

FIG. 7. STAIRWAY AFT OF FIRST-CLASS DINING-SALOON.

THE TRANSATLANTIC LINER "PARIS."

CONSTRUCTED BY THE CHANTIER ET ATELIERS DE ST. NAZAIRE.

FIG. 8. MAIN STAIRWAY.

FIG. 9. FIRST-CLASS SMOKING-ROOM.

The ship is divided into 15 compartments by 14 watertight bulkheads, those forward and aft extending up to the deck D and in the central part of the ship to the deck E. The boiler rooms are divided up into five such compartments; this arrangement gives a large measure of safety, not only against flooding, but also in the localisation of fire risks. Independently of this transverse division of the ship there are in the region of the stokeholds and engine rooms longitudinal bulkheads located near to the sides; these watertight subdivisions form crude oil storage compartments. If the ship sprung a leak the flow of water would most certainly be limited by the longitudinal bulkheads, since their tightness has been specially seen to in order to allow for storing crude oil, and the deck G, to which these longitudinal bulkheads extend, is above the load-water line and is also watertight. Flooding is thus out of the question both horizontally and vertically. Means are provided for preventing the ship from listing in case of flooding on one side in the event of damage to an empty hold; three powerful pumps always in pressure for the crude oil service would enable the rapid transfer of any water from one side to the other. The opening of port and starboard connecting pipes would accelerate the transfer. The double bottom under the stokehold is also set apart for the storage of liquid fuel, and is divided transversely into four compartments by the central keelson and two watertight side keelsons. All these compartments are connected to the transfer pumps and also afford a means for trimming the ship. The watertight compartments connected by piping to the pumps number 76. All the watertight doors are operated from the bridge by the Stone hydraulic device. There are 27 Maclean decked boats, 9·15 m. (30 ft.) in length; 22 boats of the same length by the Seamless Company. These boats can be towed by a decked de Conink motor-boat, of the same length, and fitted with wireless telegraph. There are besides a gig, a duty boat and eight rafts.

The ship is fitted out for 563 first class, 460 second class, 1,092 third class passengers, and 1,118 emigrants. There are no upper sleeping berths in the first-class cabins; all rooms having separate wood bedsteads. There are in the first-class quarters 141 cabins for one passenger, 163 for two and 32 for three passengers. Of these cabins, 89 are connected with a lavatory and 49 with a bath-room. The first-class accommodation further includes 46 lavatories and 32 bath-rooms. Hot and cold water is supplied. For the second-class there are provided 60 cabins for two passengers and 86 for four.

In the fore part of the B, or promenade deck, a room is set apart for gymnastic exercises, containing a number of suitable appliances. Adjoining this, and forward of the fore companion way is the children's play room, designed by Mme. Salzedo and decorated by the Société Française d'Art Industriel. Alongside the children's room is a reading room, and abaft these is the drawing-room which has been decorated by Messrs. Nelson. The main stairway of the ship and the surrounding galleries (Fig. 8) have been built and decorated from the designs of the architect, Bouwens de Boijen. They form a large hall having two floors, which is greatly appreciated by the passengers. The dome and balconies, of wrought iron, and the varnished wood panels, form a very handsome whole. The lift is close by. Forward of the main stairway is the highly decorated main saloon; another saloon is aft of the stairway. Aft of this room, and round another stairway is a bar, the florist's shop and the entrance to the smoking room. The latter room has two floors, one on the deck C and one on the deck B, connected together by an internal stairway (Fig. 9). An idea of the care which has been taken in the accommodation of the ship is afforded by the views Figs. 7 to 11 on this and the opposite page and page 106, which show the stairway aft of the first-class dining-room, the main stairway with the surrounding galleries, the first-class smoking-room, the first-class dining-room and a first-class drawing-room.

On the deck C is located the embarkation gangway for first and second-class passengers, the first-class passengers reach the ship at the central part, entering by the hall of the main stairway, where is the information bureau, the purser's and the doctor's cabins. Forward and aft of the hall and on both sides of the ship are the suites of cabins de luxe. Aft on the deck C are the second-class saloon and smoking-room located round the second-class stairway; both are highly decorated. The second-class promenade is right aft on the deck C and extends over the whole breadth of the ship.

(To be continued.)

COMPAGNIE BELGE DE CHEMINS DE FER ET D'ENTREPRISES.—We are informed that the Compagnie Générale de Chemins de Fer Secondaries, Brussels, 33, Rue de l'Industrie, has changed its name to that given in the title of this paragraph. The address remains the same. The new name is more in accord with the scope of the business dealt with by the concern.

UNIVERSITY COLLEGE, LONDON.—The following awards have been made at University College, in the Faculty of Engineering: Andrews scholarship (first year), B. W. Huntsman; Goldsmid entrance scholarship (second year), L. W. Ball; Archibald P. Head medal and prize, F. W. Neville; L. F. Vernon-Harcourt prize (civil engineering), A. I. W. Jones and J. P. Porter (equal); Chadwick medal and prize, J. P. Porter. Diplomas in engineering have been obtained by the following: *Civil and Municipal*: J. R. Buchanan, L. H. Clemetson, C. L. Hare, A. I. W. Jones (with distinction), W. Manning, J. P. Porter (with distinction), C. J. Pybus, A. Ross, S. W. Saunders. *Mechanical*: F. A. Blundell, D. G. Hanney, F. W. Neville (with distinction), H. R. H. Ward, J. B. Watson, L. G. H. W. Williams, H. L. Wood. *Electrical*: E. F. Anderson, H. E. M. Barlow (with distinction), J. R. Harding, R. A. E. Parsons, V. W. Roskilly.

THE NATIONAL PHYSICAL LABORATORY.

(*Continued from page* 12.)

IN proceeding with our comments on the work of the National Physical Laboratory in 1920, we pass next to the aerodynamics department.

Aerodynamics Department (superintendent, Mr. R. V. Southwell, M.A.; principal assistant, Mr. E. F. Relf, A.R.C.S.; senior assistants, Messrs. J. R. Pannell and A. Fage).—The development of the aerodynamic division of the Engineering Department has taken such dimensions that the division has been converted into a separate department, of which Mr. Southwell, of Cambridge, has been appointed superintendent. Most of the work reviewed in the Report for 1920 was still done under the guidance of Dr. Stanton, to whose inspiring leadership Mr. Southwell expresses his deep indebtedness.

Duplex Wind Tunnel.—The construction of a wind tunnel, 14 ft. wide by 7 ft. high, *i.e.*, of double the width of the three 7 ft. square tunnels, was adopted with the object of experimenting at increased speed on larger models. To study the problem Mr. J. H. Hyde first experimented on a model tunnel of 28 in. by 14 in., through which the air was drawn by two propellers of 18 in. diameter. The experiments showed that a square tunnel, though preferable for general work, would be more costly than a rectangular tunnel of double width, as it would require four propellers. The actual dimensions of the building were then fixed at: Length, 150 ft.; width, 50 ft.; height, 40 ft. and a further tunnel model on a scale of about one-eighth full size, 22 in. by 11 in., made up largely of cardboard, was placed in a special building of one-eighth the dimensions of the full building. The double width admits of experimenting with aeroplane models of large scale, and with the higher speed available the experimental conditions can be brought nearer to full-scale work than was previously possible. A constricted channel, further to increase the speed, was also tried, but was not adopted.

The measurements of the velocity distribution indicated the necessity of lengthening the channel, but the length could not be provided without shortening the distributor. To meet this difficulty Mr. Hyde designed a new form of distributor. A cellular honeycomb wall was carried right across the building, at the end of the straight portion of the tunnel; beyond this wall the tunnel branches into two expansion cones, each leading to a short circular portion in which an air screw works. The honeycomb divides the whole building up to the roof into two halves, so that the visitor only sees part of the tunnel. By September, 1920, the new tunnel was practically ready for calibration, and the calibration, since completed by Mr. Relf, shows that the new tunnel, which gives velocities up to 110 ft. per second, admits of as highly accurate work as its predecessors. The wall adds markedly to the steadiness of the wind in the tunnel, and is apparently more effective in breaking up the outflowing stream from the air screws than the distributors or diffusers (built up of vertical laths) in the older tunnels. The wall is constructed of hollow bricks, leaving slightly more than half the wall-area open.

In order to ensure steady flow in the tunnel the two electric motors, each of 200 horse-power and 400 volts direct current, are synchronised. This has been effected by taking a three-phase tapping from the armatures of the two motors to slip rings and by connecting the corresponding rings through a resistance of 5 ohms. During the preliminary experiments driving by one or two motors with various mechanical gearings had been tried, but electric synchronising is now entirely relied upon.

Measurements, Roof Balance.—Suspension of the models by means of wires is becoming the standard method of the Laboratory, and the forces on the models will be measured by means of balances, due to Mr. Relf, which are placed on the roof of the tunnel. Only one of the two balances wanted is so far ready. The principle of the action is shown diagrammatically in Fig. 5. The aeroplane model is mainly supported by two steel wires attached to the wings and hanging from a single weigh-beam A. The tail of the model is held by a single wire hanging from a second weigh-beam B. The model is prevented from swinging back under the drag force by a horizontal strut S, which presses against the lower end of a bell-crank lever C.* The sum of the readings of the weigh-beams A and B gives the lift on the model, while the beam C records the drag. Since the lift is measured in two parts, at A and at B, there are sufficient data also for the calculation of the moment about any axis perpendicular to the plane of symmetry of the model; thus the pitching moment is determined. The two wires supporting the wings pass over pulleys to a windlass on the weigh-beam A, and by winding up the wires on this windlass the angle of incidence of the wings can be varied over the desired range.

While the balances are being completed, the tunnel is being used to investigate the problems involved in the lateral stability of an aeroplane. The model is supported entirely by means of wires in such a way that it is free to yaw and also to roll about an axis passing through its centre of gravity. Four quantities, the rotary derivatives of the theory of aeroplane stability, are being measured. Two of these are simply the damping coefficients in yaw and roll produced by the wind. To measure the damping of the rolling motion the yawing is prevented by an additional wire, and the rolling motion is controlled by means of springs, one of which is

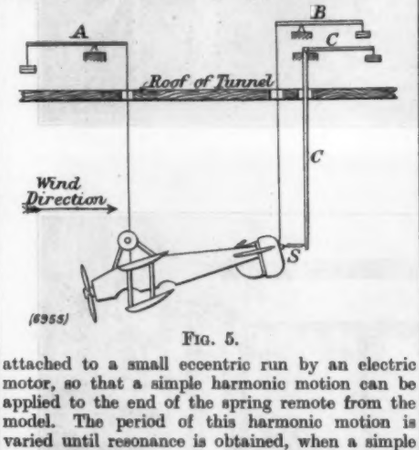


FIG. 5.

attached to a small eccentric run by an electric motor, so that a simple harmonic motion can be applied to the end of the spring remote from the model. The period of this harmonic motion is varied until resonance is obtained, when a simple relation holds between the damping to be determined and the amplitudes of the forcing and forced motions. The remaining two rotary derivatives are essentially the magnitude of the couple about each axis produced by an angular velocity about the other. To measure, for instance, the rolling couple produced by an angular velocity in yaw, a simple harmonic motion in yaw is applied by a rigid connection from the eccentric to the model, while the rolling motion is controlled by two springs. A resonance method is again possible, but it is found better to observe the combined motion in roll and yaw (by means of a mirror and beam of light to be referred to again later), and to adjust the period of the forced yawing motion until there is no phase difference between the roll and yaw, *i.e.*, until the spot of light follows a straight path. A very simple relation then connects the derivative to be determined and the damping and rolling motions previously determined. The small mirror alluded to is fixed to the model and throws its spot of light on a ground glass window in the tunnel wall. When no phase difference exists, the spot travels to and fro in a straight line; under other conditions ellipses and very complex curves are described. This method of observation looks easy and is not likely to tire the observer.

As a result of these experiments on a typical model it is hoped that the complex problem of lateral stability, the chief problem now under systematic investigation, may be reduced to a fairly simple calculation such as can be made in the drawing office during the design of a machine. At present this is only possible for longitudinal stability which is a simple problem for which more experimental data are available.

Air Screws.—The work of pressure-plotting over an air-screw has been completed, and the results are being utilised to clear up some points of the aerodynamic theory of air screws. The chief instrumental difficulty was the design of oil seal to transmit a pressure or suction of several feet of water from the rotating air-screw to the manometer. Measurements have been made over eight blade sections and for five working conditions of the screw, including the case of rotation at a stationary point. The general shape of the pressure diagram for a blade section was found to agree closely with corresponding diagrams for aerofoils of similar shape, and the thrust, as calculated from the pressure distribution, agreed within 1 per cent. or 2 per cent. with the directly-measured thrust, whilst the calculated torque was about 86·5 per cent. of the measured value. The air-flow around an air-screw determined on a model screw 3·9 ft. in diameter (the usual size is 3 ft.) established the soundness of Froude's momentum theory. In the measurement of the performance of screws for airships, airship models and screw models cannot be used for the relative dimensions of aircraft tests.

Aeroplane Wings and Complete Models.—Autorotation experiments (on models so mounted in the channel that they will rotate by themselves) have been made on a biplane on which stagger and *décalage* were varied. A plane with positive stagger (top plane forward) has a much smaller tendency to spin than a plane with a negative stagger. The effect of *décalage* (difference of incidence of the two planes, hardly applied in this country) is less marked. The Air Ministry have decided that models shall be made of all aeroplanes likely to be manufactured in numbers. Specifications for such models have been drawn up in the Laboratory, and the models, though the property of the Ministry, will be kept in the Laboratory; these complete models will be tested for lateral stability. Of other models tested mention is made of the Woyevodsky type in which wings and fuselage form a single structure without external bracing. From the aerodyamic standpoint the arrangement offers considerable advantages, but there is so far no experience as to the control of such aeroplanes in flight.

Airships. Parachutes.—Experiments on towing and mooring airships have been conducted on partly or fully-rigged models of an S.S.Z. non-rigid airship. The need of an improved form of nose stiffening was recognised and led to the adoption of a cone which was found not to affect the pressure distribution in its rear. Towing experiments are being made in water with a stream-like body and a sphere in order to ascertain the effect of acceleration on resistance. The full-scale experiments made concern modification of the upper vertical fin as well as petrol consumption and other features. For the fin experiments the airships R. 33, R. 26, R. 29 were used; the fin size is reduced and the turning coefficient (diameter of the turning circle divided by the length of the ship) is determined. For a rigid airship a turning coefficient of less than 7 is regarded as satisfactory; as the fin area of R. 29 was reduced in the ratio 100 : 76 : 50, the coefficient decreased from 9·8 to 9 and 6·7; there was thus an advantage in rendering the upper fin inoperative. As regards parachutes little has been done during the past year, but the conclusion is confirmed that parachutes, made deep enough to ensure a positive hoop tension at all points, fall as rigid bodies and are much more stable than when made to the existing standard pattern.

The William Froude National Tank.—(Superintendent Mr. G. S. Baker, late R.C.N.C., M.I.N.A., Mr. J. L. Kent, Miss E. M. Keary, Messrs. G. H. Bottomley, C. Wigley, A. W. Riddle.)—Sir William E. Smith has succeeded the late Lord Rayleigh as chairman of the Advisory Committee, on which Colonel Crompton and Sir Thomas Fisher have replaced Sir Horace Darwin and Mr. C. Livingstone. The test work for the mercantile navy showed a steady increase during 1920, 69 models of 37 designs having been tested by November, against 66, 41 and 44 in 1917–18–19, but the work has fallen off somewhat since. In many cases the tests have led to a reduction of the propelling power required at service speeds —as much as 10 per cent. in one instance. The tank staff has been sufficiently strong for this work, though it may be necessary to extend the working

hours. As regards research, matters are unfortunately different. The committee have for some time been considering the advisability of building another tank, next to the actual one, for higher-speed experiments. More directly urgent is the need of fitting up the small tank in the present building for screw and other experiments in flowing water in order to investigate, *e.g.*, the stream lines around certain models, an investigation which has practically been suspended since 1916. In the small tank the water is circulated by a 10-h.p. motor at 3 ft. per second through a cross-section of 17 sq. ft.; higher speeds and more uniform flow are highly desirable, but difficult to obtain. But want of funds is the main obstacle to research. The Institution of Naval Architects has issued a special appeal for contributions to the research fund to interested firms, with some gratifying response. The present position of the shipbuilding industry, however, curtails liberal private support; officially little is to be hoped for, and yet starvation of research would be fatal, and this field, one might feel inclined to add, is strangely unpopular. The man in the street may have peculiar opinions as to the value of research, and it would probably not occur to him that means are lacking for the advance of navigation, and that it has not been possible, for instance, to continue the inquiry into the inter-action between passing ships.

Wave-making Apparatus.—The apparatus for wave-making is mounted at the southern beach end of the tank. A board, 3 ft. wide and 28 ft. long, is hinged to an iron frame lying across the tank, and is rocked to and fro by a 5-h.p. motor. The period is adjusted so that waves about 3 in., 4 in., 5 in. high are produced, corresponding to actual waves ranging from 2 ft. up to 6 ft. for a wave-length of 600 ft. and to waves of a maximum height of 12 ft. for a wave-length of 120 ft. The motion is only maintained for about a minute, and the flap is then lowered, so that the reflected wave has time to break on the beach. The waves have been found to be approximately trochoidal in shape; groups of irregular waves can also be produced and reproduced. Various problems are studied with the aid of this apparatus: the increase in the mean resistance of a low-speed cargo boat over the still-water resistance when propelled head on through various waves, the effects on resistance and weather qualities of V and U-shaped bow sections, with and without flare above the low-water line, the effects of ship's speed and length on pitching, and the effect of the longitudinal radius of gyration on resistance i.e., the effect of end or central loading. So far as possible the length of a cargo boat should be suited to the wave-length usually encountered on its trade route, data as to which are now collected. Boats, Mr. Kent finds, meet waves of long period without breaking up the water surface, i.e., the pressure changes are gradual. But when the wave period comes up to the natural pitching frequency of the ship, heavy pitching occurs, the pitching in itself involving rapid changes in stream-line motion and consequent dissipation of energy. With short-period waves pitching is negligible, but when these waves are high, they are broken up, and each crest met produces a retarding blow.

Manœuvring Power of Ships. Screw Propellers.—In demonstrating on the inspection day the action of the water on the rudder and the action of the udder forces on the ship as a whole, Mr. Baker propelled, by its own electric motor, a 17-ft. model of a fine-lined cargo boat provided with an ordinary rudder. On the boat was a frame rotating with the rudder post, and the torque on the rudder in different positions was measured by means of springs, the turning power being at the same time determined by means of two dynamometers placed forward and aft in the hull; the boat was run at 8 knots and 12 knots. The experiments show that the old-fashioned rudder does its work fairly well. But the effects of the shape of the rudder, the presence in ships of varying prismatic coefficients and of propeller race on manœuvring power are being investigated. In the screw-propeller work the boat is towed by the machine, and the propeller-shafts are suspended from an independent part of the carriage and kept at the desired position near the stern by regulating the speed of the electric motors driving the propellers; in this way the effects of varying position, screw diameter pitch and rake, &c., can be determined. The determination of the wake and thrust deduction fractions are important features in these experiments. The wake fraction is defined as the fractional excess of the velocity of the ship over that of the wake water in which the screw is working; the fraction is expressed in per cent. and may vary very much; for twin-screw boats 20 per cent. is perhaps an average, in destroyers the value may be zero or become negative. The thrust deduction fraction, the fractional excess of the screw thrust when the model is self-propelled over the model resistance when towed without screws, rarely exceeds 25 per cent.

Steam Ship Trial Data. Skin Friction.—The analysis of the trial data of steamers now undertaken by the Department promises to be an important help. Much more can be learnt from these data and tank experiments than from either of the two modes of examination alone. As regards skin friction Mr. Baker compared, in the papers brought before the North East Coast Institution of Engineers and Shipbuilders in 1915 and before the Institution of Naval Architects in 1916, the various recorded data on skin friction. Having resumed these studies Mr. Baker has convinced himself that the often-quoted tables of Tideman are not based on any actual experiment by that writer. Inquiries by Professor Cop, of the Technical High School at Delft, make it fairly certain that friction experiments as such, were not made by Tideman at the Rijks Wharf, Amsterdam, and that Tideman's Table B is merely Tideman's version of Froude's table. It seems to be one of the not infrequent cases that a mistranslation is copied unchecked and then passes from one book into another.

Aeronautical Work.—Experiments on full-sized flying-boats have been made, in parallel with tank experiments, at the Isle of Grain experimental station, in order to determine the blow experienced by the hull when settling on the water or when taxying to fly off. After damaging one machine a second machine was built, 12,000 lb. in weight and for speeds of 75 knots to 80 knots like the first. The pressures per square inch of bottom amounted to 4·8 lb., and locally reached 8·7 lb. per square inch when landing among waves. Similar experiments are required on an elastic hull (the others being rigid) of the Linton Hope type.

(To be continued.)

MOTOR-STARTING APPARATUS.

In our issue of January 28 last, on page 105, we illustrated and described a new time lag for electrical switchgear made by the Electrical Apparatus Company, Limited, of South Lambeth-road, London, S.W.8, and also dealt briefly with recent developments in the organisation of that concern. We then mentioned that an amalgamation had been effected between the above-mentioned firm and Messrs. Bray, Markham and Reiss, Limited, of Walthamstow, and we now propose to describe some of the recent productions of this combination which appear to be of interest to engineers in general. As our readers are doubtless aware, the last-named firm have been engaged for many years in the manufacture of motor-starting and controlling apparatus, but their output, both before and during the war, was mainly absorbed by the Admiralty for use on H.M. ships and in the naval establishments at home and abroad. The reduction in naval construction work which followed the Armistice, however, has made a larger proportion of the apparatus available for use at sea in the mercantile marine, as well as for various land applications in engineering and other works.

The drawings reproduced in Figs. 1 and 2 on page 100 are, respectively, front and side elevations of a small and simple starter which has been largely employed in the Navy for controlling forced draught and ventilating fans. The particular example illustrated is suitable for motors up to 40 h.p. at pressures up to 500 volts. Its special feature is that no slate is employed in its construction, the use of this material having been avoided on account of its liability to fracture from the effects of heavy gun fire. Instead of slate, a cast-iron plate is employed for mounting the resistance contacts, which are formed by studs carrying copper rollers, the studs being insulated from the plate by mica. Fig. 4 shows the plate complete but with the contact arm removed, the latter being illustrated separately in Figs. 5 and 6. The contact arm is a heavy cast-iron plate carrying two pairs of rockers to the ends of which contacts, in the form of semi-discs of copper, are fixed in such a manner that they can be readily replaced. Each pair of rockers is forced apart by a helical spring, and the two contacts are electrically connected by flexible copper braiding visible in Fig. 5. When the arm is in position, one pair of contacts bears on the vertical face of the copper quadrant shown near the central pivot in Fig. 4, while the other pair makes contact with the sides of the rollers. By turning the arm through 90 deg. in a clockwise direction the resistance in the armature circuit is varied from a maximum to zero, as will be understood from the diagram of connections reproduced in Fig. 3. The arm is held in the full-on position, against the action of a spring, by the usual "no-volt" coil, and an overload coil, the construction of which is shown on the right of Fig. 1, is also fitted.

An important feature of the design is, however, the provision of a magnetic blow-out device, which is operative in all positions of the contact arm. This is obtained by fitting a coil round the pivot of the arm as shown in Fig. 4, and also indicated in the diagram Fig. 3. The coil, which is in the field circuit, produces a magnetic flux through the arm, and this flux passes across the air gap in the neighbourhood of the contact rollers, returning through the base plate. The direction of the flux near the rollers is, therefore, at right angles to the length of the arc formed when a contact is broken, and thus the arc is effectively extinguished.

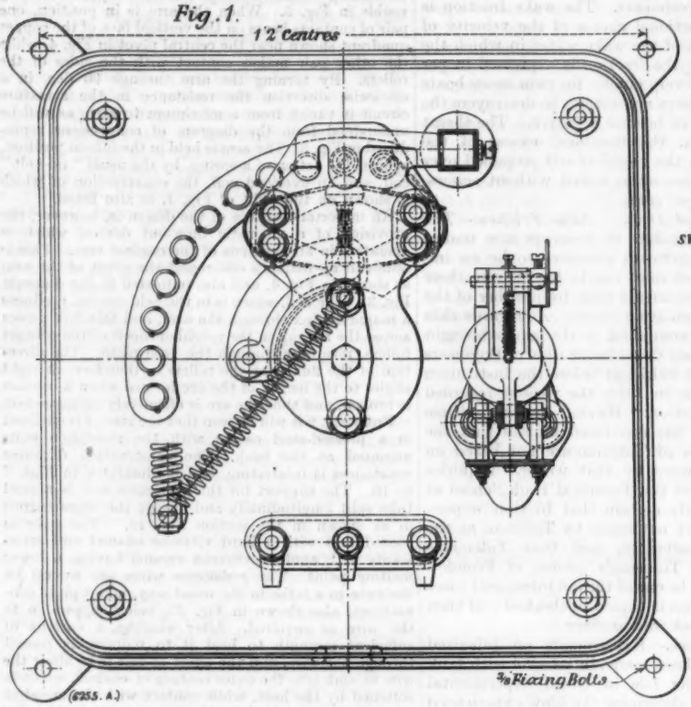
From Fig. 2 it will be seen that the starter is enclosed in a pressed-steel casing with the resistance units mounted at the back. The construction of these resistances is interesting, and is illustrated in Figs. 7 to 10. The support for the resistance wire is a steel tube split longitudinally and having the edges turned in as shown in the section Fig. 10. The tube is coated first with a hard vitreous enamel and afterwards with another vitreous enamel having a lower melting point. The resistance wires are wound on the tube in a lathe in the usual way, metal plate connections, also shown in Fig. 10, being slipped on to the wire as required. After winding, a current of sufficient strength to heat it to redness, is passed through the wire, and the effect of this is to allow the wire to sink into the outer coating of enamel, which is softened by the heat, while contact with the metal of the tube is prevented by the inner coating of harder enamel. The spring of the tube, of course, takes up any slack in the wire, and the latter is securely fixed in the enamel when cool. Porcelain button insulators are fitted in the ends of the tube which is mounted between two steel strips, steel spring washers being placed between the strips and the insulators, and the whole clamped up by means of a bolt passing through the axis of the tube. The bolts, it will be noticed in Fig. 9, are fitted into slots in the steel strips, so that any unit can be removed without disturbing the remainder by slacking back one of the nuts.

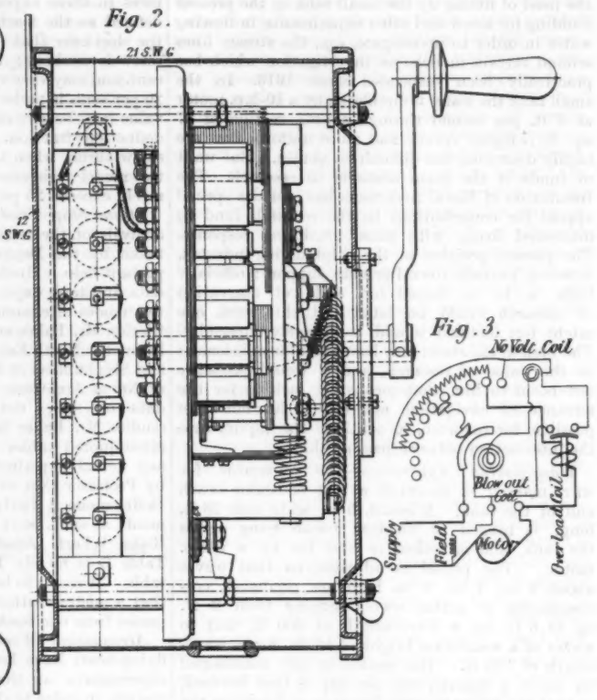
In Figs. 11 and 12, page 101, we show a starter of similar design, but provided with double-pole cartridge-type fuses and with a shunt regulator for speed control. This starter, which is suitable for motors up to 20 h.p. at 200–500 volts, forms a particularly compact unit, and its small overall dimensions, which are indicated in the illustrations, render it convenient for mounting directly on machine tools or other machinery. As will be seen, it is enclosed in a cast-iron water-tight casing, through the cover of which the starter contact arm is operated by a lever handle, while the shunt regulator is controlled by a handwheel. On the right of Fig. 12, an alternative method of operating both the starter and shunt regulator by means of loose key handles is indicated. The electrical connections are shown in the diagram, Fig. 13, and from this, as well as from Fig. 11, it will be seen that the starter is of the double-pole type, so that no external main switch is required. The main contacts and those of the shunt regulator are both of the copper-roller type described above, and a magnetic blow-out is provided for the former; this device is, of course, unnecessary on the shunt regulator. Current is conveyed to the contact arm of the latter by means of a spring arm bearing on the edge of a copper disc as illustrated in Fig. 11, and indicated diagrammatically in Fig. 13. A "no-voltage" release is provided in this starter, but the fuses are relied upon for overload protection. The usual overload release can, however, be fitted if desired in place of the fuses.

A type of starter made by the Electrical Apparatus Company, Limited, and illustrated by the photograph reproduced in Fig. 14, has been specially designed for use with electrically-driven printing machinery. It is known as an "inching starter," since it allows the machine to be run for a few revolutions, and frequently started and stopped, during the process of making ready, but it is equally suitable for the control of any other machinery which has frequently to be started and stopped on full load. We have already illustrated and described a starter of this type, on page 552 of our 101st volume, and to that article we must refer our

MOTOR-STARTING APPARATUS.

CONSTRUCTED BY THE ELECTRICAL APPARATUS COMPANY, LIMITED, ENGINEERS, VAUXHALL WORKS, LONDON.





readers for a full explanation of the principles on which it operates. The design has, however, been improved in several respects since that time, and it may, therefore, be of interest to deal briefly with it again. The special features of this starter, it may be recalled, are that the "no-voltage" and overload releases are fully operative while starting up as well as when the motor is running; the circuit is always broken by contactor switches having carbon breaks and magnetic blow-outs; and that if the handle is released or moved backwards during the operation of starting up, the circuit is instantly broken and the motor cannot be re-started until the handle has been returned to the first position. It is, therefore, suitable for heavy work with unskilled operators.

Referring to Fig. 14, it should be explained that the starting handle, is free to move through a small angle in either direction before moving the contact arm, although both are mounted on the same spindle. The resistance in the armature circuit is cut out in the usual manner by moving the starting handle in a clockwise direction, the current flowing from the uppermost continuous sector to the contact segments through cylindrical plungers and a copper connection seen on the upper end of the contact arm. The contact segments, it will be noticed, are formed with semi-circular projections on one edge and with similarly shaped recesses on the other edge, and thus linear, instead of point, contact is obtained as the plunger passes from one segment to the other. The two sectors below the spindle of the contact arm we shall refer to as the inner and outer sectors, and, of these, the inner is connected directly to one of the mains and the outer through economy resistances to the operating coils of the contactor switches, and thence to the other main. The movement of the main contact arm is limited by a buffer at each end, and these buffers each carry a small spring contact lever situated near the ends of the lowest sector and distinguishable in Fig. 14. The contact lever on the right is connected directly to the operating coils of the contactor switches, without including the economy resistances in the circuit, and the other contact lever is connected to the inner sector.

The lower end of the main contact arm carries two insulated plungers, one of which bears on the inner sector and the other on the outer sector. The lower plunger carries at its upper end a small spring-controlled switch which connects the two plungers electrically when the starting handle is moved in a clockwise direction in a manner which will be easily understood by reference to the illustration. The lower end of the same plunger is arranged so that it presses against the

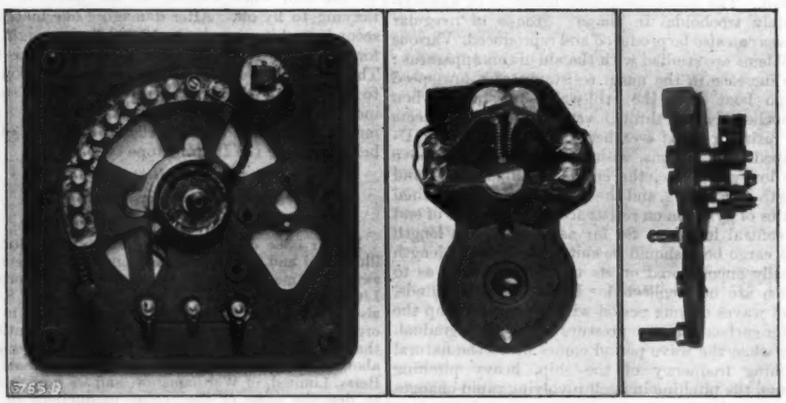
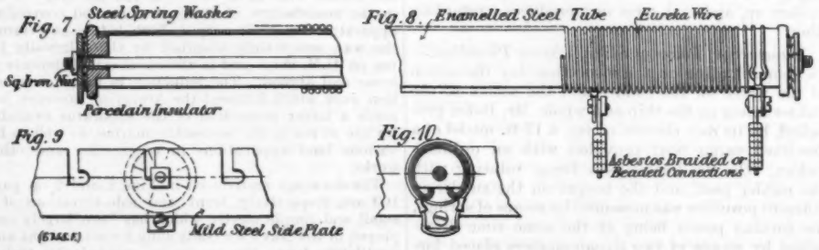


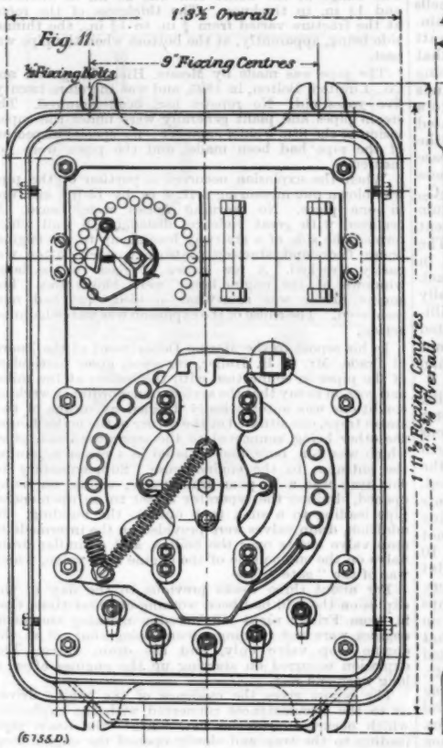
FIG. 4. FIG. 5. FIG. 6.

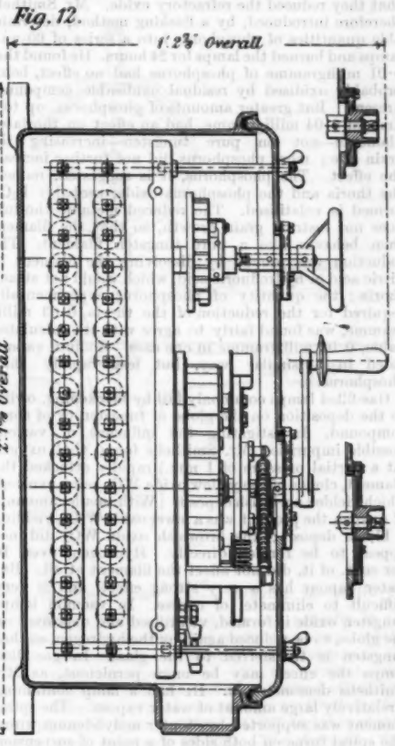


spring contact levers mounted on the buffers when the main contact arm is at either end of its travel. When the external main switch is closed with the contact arm in the starting position, nothing happens until the starting handle is moved in a clockwise direction so as to close the small switch on the contact arm, but when this has been done, current flows from the inner sector through the plungers and small switch to the spring contact lever on the right-hand buffer, and thence through the coils of the contactor switches to the opposite line. The contactors then close and the motor starts with all the armature resistance in circuit. When the starting handle is moved to cut out the resistance, the connection through the spring contact lever is broken, but communication between the inner and outer sectors is now maintained by the small switch on the main contact arm. Current then flows to the contactor switch coils through the economy resistances, and is thereby reduced so that it is only just sufficient to keep the switches closed. If the handle is released, or moved backwards, in any intermediate position, the small switch on the contact

MOTOR-STARTING APPARATUS.

CONSTRUCTED BY THE ELECTRICAL APPARATUS COMPANY, LIMITED, ENGINEERS, VAUXHALL WORKS, LONDON.





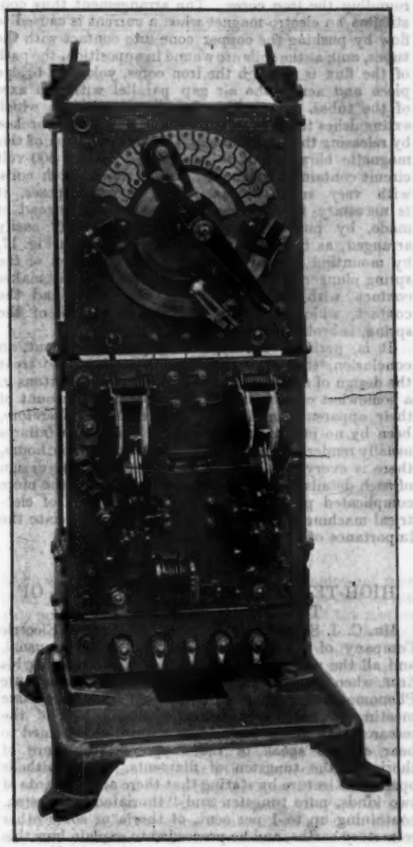


FIG. 14.

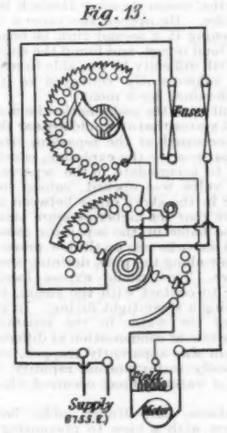
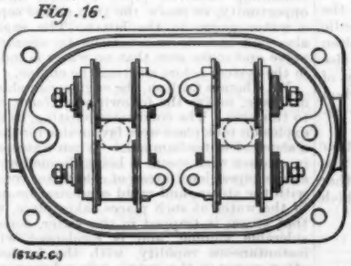
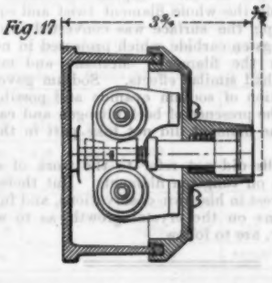


FIG. 15.





arm will open and break the circuit through the contactor coils, thereby opening the main circuit. The contactor switches cannot be closed again until the contact arm has been returned to the first position, because the current which would flow through the coils of the contactor switches if the small switch on the contact arm were closed with the arm in an intermediate position would be insufficient for the purpose. When the contact arm is in the full-on position, however, the starting handle can be released, since, in this position, the switch on the contact arm is short-circuited and electrical connection between the inner and outer sectors is maintained through the spring contact lever on the left-hand buffer.

It will now be obvious that "no-voltage" protection is obtained, as above stated, both during the operation of starting-up and when the motor is running normally, since a failure of supply will be followed immediately by the opening of the contactor switches. Overload protection is provided by the small horizontal coil which can be seen in Fig. 14 on the lower part of the panel between the two contactor switches. This coil carries the main armature current and controls a switch in the circuit containing the coils of the contactor switches, breaking this circuit, and thus opening the contactor switches, when the armature current exceeds a pre-determined amount. The device is, of course, operative during starting and running, and it will also be evident that it is impossible either to close the circuit on a "short" or to hold it closed in this condition, both of which can be done with a starter of ordinary design. It should also be clear that no slow-motion gear is necessary, since if the starting handle is moved too rapidly the overload coil will operate and open the main circuit.

The inching starter can, if desired, be arranged for remote control by means of push-button switches, and the type of push-button used for this purpose, as well as for the operation of other automatic starters of the contactor type, is illustrated in Figs. 15 to 17. It is of particularly substantial construction, both mechanically and electrically, and is distinguished from the push buttons usually employed for this class of work by the fact that it is provided with a magnetic blow-out to extinguish the arc formed when the circuit is broken. This provision is desirable because push buttons are generally included in highly-inductive circuits, and its effect is, of course, to prevent burning of the contacts. The arrangement of the parts will be clear from our illustrations, which show the duplex form with both starting and stopping buttons. The body and cover are iron castings held together by cheese-headed screws, the edge of the body fitting into a recess in the cover and a watertight joint being made by means of a rubber ring as shown in the transverse section, Fig. 17. Connection is made by pushing a truncated cone of copper, carried by a spring plunger, in between a pair of cylindrical copper tubes mounted on an iron bridge piece screwed on to the cover. The copper tubes contain iron cores connected at one end by the bridge piece, and at the other end by an iron yoke on which insulated terminals are

mounted. The leads from the external circuit, which enter through holes in the body tapped for screwed conduit are connected to the terminals, and the latter are connected to the copper tubes through coils surrounding the iron cores. The arrangement thus constitutes an electro-magnet when a current is caused to flow by pushing the copper cone into contact with the tubes, and, as the coils are wound in opposition, the path of the flux is through the iron cores, yoke and bridge piece and across the air gap parallel with the axes of the tubes. It is this flux in the air gap which extinguishes the arc formed when the contact is broken by releasing the push button. By the provision of this magnetic blow-out, it is possible to open a 500-volt circuit containing solenoids, or contactor-switch coils, with very small breaks. For some purposes, it is necessary for a circuit to be broken, instead of made, by pushing the button, and this is easily arranged, as indicated by the dotted lines in Fig. 17, by mounting the copper cone on an extension of the spring plunger. In this case, the cone normally makes contact with the far side of the tubes, and the contact, which is maintained by the action of the spring, is broken when the button is pushed in.

It is, perhaps, hardly necessary to point out, in conclusion, that there has been a tendency to treat the design of such minor accessories as push buttons in a somewhat cursory manner—probably on account of their apparent simplicity. Failures have, therefore, been by no means infrequent, and since such failures usually render expensive machinery idle for some hours, there is every justification for considering the design of such details at least as carefully as that of the more complicated parts of an installation. Users of electrical machinery, we are confident, will appreciate the importance of reliability in such parts.

HIGH-TEMPERATURE PHENOMENA OF TUNGSTEN FILAMENTS.

MR. C. J. SMITHELLS, B.Sc., of the General Electric Company of London, was given a rather unusual, and all the more welcome, amount of latitude by his firm when reading a paper on "High-temperature Phenomena of Tungsten Filaments" before the June meeting of the Faraday Society, on behalf of the research staff of the firm. One is quite accustomed to hear experts speak of the supposed admixture of thoria to the tungsten of filaments. Mr. Smithells opened his lecture by stating that there are filaments of two kinds, pure tungsten and "thoriated" tungsten, containing up to 1 per cent. of thoria or some other refractory earths, and he proceeded to explain how this admixture influences the crystal growth in the filament and its life. In the second part of his paper he dealt with the chemical reactions occurring in gas-filled lamps, with special regard to the blackening of the lamps.

Langmuir showed in 1913 that the blackening of vacuum lamps is due to the volatilisation of the tungsten, and that it can be suppressed by filling the lamps with an inert gas such as nitrogen or argon. In such an atmosphere the filament glows at a higher temperature than in a vacuum bulb, viz., at 2,500 deg. K., instead of 2,300 deg. K., and the efficiency, 0·8 candle per watt in the vacuum bulb, is raised to two candles in the gas-filled lamp, which is hence known as the half-watt lamp. The filaments of these latter lamps are always made spiral to reduce convection and conduction losses, but they are exposed to more severe strains in gases at approximately atmospheric pressure; hence vacuum filaments may fail in gas-filled bulbs. Before burning, the wire filament has a fibrous texture and is ductile; on heating, the filament breaks up, owing to crystal growth, and loses its ductility. To study these phenomena Mr. Smithells took a series of similar lamps and burned them for various periods, from a fraction of a second to several hundred hours. The globes were then broken open, and sections were made of the filaments. The photographs exhibited were exceedingly interesting, but they would require very careful reproduction to bring out the characteristic points. In pure tungsten filaments grain growth continues until the diameter of the crystals equals that of the wire. The average size of the crystals then remains fairly unchanged; but the conditions are not stable, and the crystal boundaries are in constant motion. The final crystal size may be attained in 15 minutes, and a filament will look, after 600 hours, very much like a filament which has been burning for 20 hours. But the filaments sag and become deformed in addition to turning more angular and crystalline. The coarse-grain filaments are more brittle than the fine-grained.

This grain growth now is retarded by the thoria, which probably segregates in the crystal boundaries, so that after 600 hours burning the grain will appear still fine. The ductility has been destroyed by equiaxing; yet the fine-grain structure is very tough and the sag small. Even thoriated filaments may develop a coarse structure and turn brittle under certain conditions, *e.g.*, when red phosphorus or also metallic sodium has been introduced, as is done in practice to remove traces of oxygen from the globe. Both these substances are reducing agents, and it seemed probable that they reduced the refractory oxide. Mr. Smithells therefore introduced, by a flashing method, determinable quantities of phosphorus into a series of 60-watt lamps and burned the lamps for 24 hours. He found that 0·01 milligramme of phosphorus had no effect, being probably oxidised by residual oxidisable compounds present. But greater amounts of phosphorus, up to a limit of 0·04 milligramme, had an effect on thoriated filaments—not on pure tungsten—increasing the grain size; more phosphorus did not further increase the effect. The phosphorus, it is suggested, reduces the thoria and the phosphorus oxide, probably P_2O_5, formed is volatilised. The reduced metallic thorium does not restrain grain growth, so that the filament then behaves like a pure tungsten filament. The reduction was proved by dissolving the filament in nitric acid or hydrofluoric acid, which would not attack thoria; the quantity of phosphorus experimentally required for the reduction of the thoria, 0·03 milligramme, was found fairly to agree with the calculated value, 0·02 milligramme in one case. Sodium vapour acted in a similar way, but less rapidly than phosphorus.

Gas-filled lamps commonly fail by blackening, owing to the deposition on the globe of tungsten or of some compound. Investigating the influence of various possible impurities, Mr. Smithells found that oxygen (at a partial pressure of 1 mm.) rapidly attacked the filament, clouds of the yellow oxide WO_3 being evolved, which yielded a whitish deposit. With smaller amounts of oxygen the product was a lower oxide W_2O_5, yielding a bluish deposit; the brownish oxide WO_2 did not appear to be formed directly. Hydrogen, even 10 per cent. of it, did not affect the filament at all. But water vapour has a very strong effect, and is very difficult to eliminate, of course. In vacuum lamps tungsten oxide is formed, volatilised and deposited on the globe, to be reduced again by the hydrogen, so that tungsten is transferred to the glass. In gas-filled lamps the effect may be more pernicious, as Mr. Smithells demonstrated. He had a lamp containing a relatively large amount of water vapour. The spiral filament was supported by stouter molybdenum wires. The spiral turns on both sides of a point of suspension remained cold, when the current was switched on, and these dark turns were seen to grow thicker. Next to them, however, a turn or two would glow very brightly and thin out and stretch, under the pull of the other turns, until it broke. The filament failed, but not exactly at the very brightest spot, which had become very conspicuous in the demonstration. The snapping occurred within a few minutes. In the presence of less water vapour it might have taken hundreds of hours; but the cyclic character of the reaction made water vapour very destructive. Some tungsten oxide, Mr. Smithells suggested, is formed by the decomposition of the water vapour; the oxide is reduced again by the hydrogen, and the reduced tungsten deposited on the cold turns where it is incorporated in the existing crystals; part of the oxide is deposited as a brownish-black film on the globe.

Carbon dioxide, Mr. Smithells further observed, attacked the hottest part of the filament, forming a bluish oxide which might also contain carbon. Carbon monoxide had a slower effect, being probably broken down into CO_2 and carbon; the filament finally failed, somewhat as in the presence of water vapour, but it failed on the hottest part of the filament (i.e., not near the suspension points). Hydrocarbons had a very vigorous action. Naptha introduced into the bulb made the whole filament twist and squirm and break up; the surface was converted into the very hard tungsten carbide which projected in needle crystals from the filament. Methane and molten paraffin wax had similar effects. Sodium gave rise to the formation of sodium cyanide and possibly of cyanogen in the presence of both nitrogen and carbon monoxide; the filament did not take part in the reaction.

Mr. Smithells did not refer to the work of other experimenters on tungsten filaments. But there was sufficient interest in his own observations, and further communications on the crystal growth, as to which opinions differ, are to follow.

EXPLOSION OF A CAST-IRON STEEL PIPE.

UNDER the provisions of the Boiler Explosion Acts, 1882 and 1890, the Board of Trade have made a preliminary investigation as to the explosion of a steam pipe which occurred on October 19 last at the Egerton Cotton Mills, Salford, owned by Messrs. Richard Haworth and Co., Limited.

The report by the Board of Trade has just been issued, and from this we learn that the pipe in question was in the form of a bend and was made of cast-iron. Its greater length measured 6 ft. 3 in. and the shorter length 3 ft., having an inner radius of about 12 in. It measured 13⅞ in. outside diameter, varying in thickness, where fractured, from 1⅛ in. to ¾ in., resulting in an average bore throughout the major portion of the pipe of 11¼ in. The flange at the boiler end was 20 in. in diameter, and 1¼ in. in thickness. The thickness of the metal at the fracture varied from ¾ in. to 1⅛ in., the thinner side being, apparently, at the bottom when the pipe was cast.

The pipe was made by Messrs. Hick, Hargraves and Co., Limited, Bolton, in 1895, and was therefore twenty-five years old. No repairs had been required. The steam pipes and plant generally were under the supervision of the firm's chief engineer; no special inspection of the pipe had been made, and the pipes were not insured.

When the explosion occurred a portion of the pipe was blown out measuring 4 ft. 6 in. by 15 in., and was in one piece. No warning noises were heard. It occurred with great violence, dislodging a wall which formed the side of a stairway leading up to the engine-house floor and starting platform, which latter was partly wrecked. A few panes of glass in the large windows of the engine-house were blown out. The engine driver was somewhat scalded, but had now recovered. The cause of the explosion was water-hammer action.

In his report to the Marine Department of the Board of Trade, Mr. C. H. Haller, surveyor, gives particulars of the pipes in connection with the boilers at the mills, and goes on to say that the system under ordinary working conditions was automatically drained by means of two steam traps, one situated at the corner of the boiler-house, the other being connected to the separator drain pipe, which was 2-in. bore, and situated in a recess adjoining the entrance to the engine-house. Supplementary to this trap was a by-pass drain valve, which, on being opened, drained the separator direct to an open-ended pipe leading to a sunk tank outside the building. In addition, drain valves were provided on the intermediate stop valve chests over the boilers, and a similar drain valve on the engine side of the engine stop valve, which was of the "gate" type.

For about three weeks previous to the day of the explosion the mill had been working on short time, that is, from Friday night till Tuesday morning the main engines were not running, steam being shut off at the engine stop valve only, and the drain valve. The explosion occurred on starting up the engines after a long week-end rest.

The report gives the evidence of the engine driver as to the circumstances connected with the explosion, which occurred after he had "felt" the drain pipe leading to the trap and slowly opened the engine stop valve until he heard the steam passing through into the high-pressure cylinder. He opened the valve a full turn and just after opening it a second turn he heard, without any warning, a loud report, and found the engine house full of steam. With difficulty he was able to make his escape, and was subsequently conveyed to the hospital where he was detained for a mont

Mr. Haller deals in full with the examination he made after the explosion, and states that it would appear that some obstruction had occurred at the separator drain during the week-end rest prior to the explosion, causing water of condensation to accumulate in the separator, which, when the stop valve was opened, caused such a reduction in pressure in the short range between the separator and stop valve that the higher-pressure steam on the other side of the baffle in the separator caused some of the accumulated water to rise on the low-pressure side of the baffle and flow along the pipe, draining away through the stop valve. This would expose locally colder patches of water to contact with the steam, the baffle not necessarily being a steamtight fitting. In the resulting disturbance of the water in the separator and pipe due to irregular rate of condensation at different parts, some of the steam was apparently trapped, and condensed with practically instantaneous rapidity, in which process the blow of water-hammer occurred which fractured the pipe.

Certain recommendations, Mr. Haller adds, have been made to the owners with a view to preventing a similar occurrence. It is their intention to replace the remaining cast-iron pipes by steel ones at the first opportunity, to renew the trap at the separator, and fit a water gauge to the latter. The engine driver has also had specific instructions to operate the by-pass valve and make sure that no water is lodging anywhere in the system before starting the engine.

Mr. Thomas Carlton, the engineer-in-chief to the Board of Trade, makes the following pertinent observations as to this case. The conditions existing, he says, when this explosion took place were favourable for the occurrence of a shock of water-hammer. When water of condensation in contact with steam is being drained out of a range of steam pipes, local areas of cold water come into contact with the steam, and rapid condensation and disturbance of the water at such places takes place, with the result that steam is trapped in the water, sometimes in considerable volume, and is condensed with practically instantaneous rapidity, with the further result that other water in the range, being driven along to fill the place occupied by the condensed steam, produces a heavy shock of water-hammer on the motion being arrested. In this case, the force of the blow and direction were such that a piece measuring 4 ft. 6 in. by 1 ft. 3 in. was blown out of the side of the pipe, and one man was severely scalded. The pipe, however, was of very variable thickness, and was somewhat weak in consequence.

The explosion, Mr. Carlton concludes, may be said to have been due to the improper overhauling of the drain trap.

THE SYKES GEAR-TOOTH COMPARATOR.

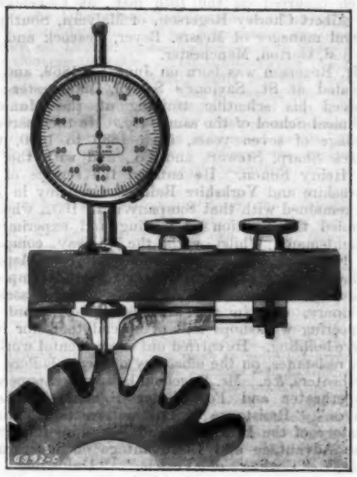


FIG. 1.

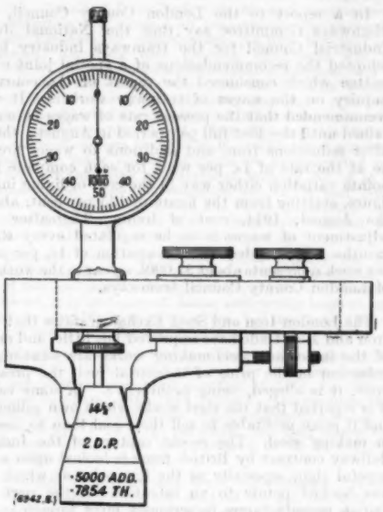


FIG. 2.

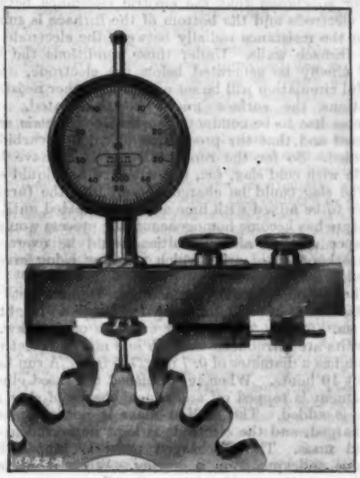


FIG. 3.

A DEVELOPMENT of the vernier type of gear tooth calliper has recently been brought out by Mr. W. E. Sykes, of Upton-road, Slough, and is illustrated in Figs. 1 to 3 herewith. This instrument is properly a comparator, though it may also be employed for making definite measurements. The principal object of the instrument is the comparison of the thickness of gear teeth and the uniformity of pitch, and the determination of inaccuracies or lack of uniformity, either between the teeth themselves or between the gear teeth and master blocks, representing a rack tooth. Another use to which the instrument can be put is the measurement of the thickness of teeth. It can be used for checking spur gears and spiral, bevel or other gears, pinion-shaped and rack-shaped cutters, &c.

The instrument consists of a short bar fitted with one fixed and one sliding jaw, arranged with a needle of a dial indicator between the two, as shown in Fig. 1. The position of the indicator can be adjusted so that the needle may be placed midway between the jaws, according to the size of the teeth being tested. In use for ordinary testing the jaws are set so that their ends are between the pitch circle and the bottom of the tooth. The instrument is then placed on a tooth and rocked over it and the dial adjusted to zero when the hand is in its extreme clockwise position. If then the instrument be removed to another tooth and rocked in a similar way the hand of the indicator will show any difference existing between the two, either of plus or minus thickness. The normal instrument has jaws for a 14½ degree pressure angle, and the dial shows the errors in tooth thickness magnified by twice the cotangent of the pressure angle. A division of 1/1000 in. represents $\frac{\cdot001}{1\cdot933} = \cdot000517$ in. on the thickness of the tooth, practically half of one thousandth of an inch.

For the actual measurement of teeth standard blocks are furnished for the purpose of setting the jaws. These blocks are marked with two lines, one representing the addendum line and one the working depth line of the standard 14½ degree rack tooth of the pitch in question. As shown in Fig. 2, the jaws are set so that their tips lie between these two marks, and the indicator adjusted or reading noted. The instrument is then transferred to the gear tooth and the difference in the dial reading taken. In the usual sets as made up with seven standard blocks it is possible to measure every pitch, both standard and non-standard, between the range of 12 D.P. and 1 D.P., from ¼ in. to 3 in. circular pitch, and from 2 mm. to 25 mm. module. With six blocks all pitches between 12 D.P. and 1½ D.P. can be measured. This may be done because it is possible to measure by the dial the difference in the setting which would be required for a block not actually included in the set, compared with the standard block available. The difference between the blocks consists mainly in their width at the top. This width is equivalent to the thickness on pitch line — (addendum × 2 tan pressure angle).

For standard B. and S. proportions and 14½ degree pressure angle a constant equal to 1·0536 can thus be obtained for diametral pitches. The 1 D.P. block is made proportional to this, and all other pitches are in direct proportion, and their width at the top may be obtained from the expression $\frac{1\cdot0536}{\text{D.P.}}$. Having the width for any intermediate or other block not actually in the set, the calculation of the dial reading is a simple matter and is obtained by multiplying the difference in the block widths by the figure 1·933, the product being the difference in the dial reading. Instead of working in this way the procedure may be modified by first multiplying the figure 1·0536 by 1·933 and thus obtaining a new constant (2·037). The formula then becomes—

$$\text{Difference on dial} = \frac{2\cdot037}{\text{D.P. of block}} - \frac{2\cdot037}{\text{D.P. of tooth to be measured}}$$

Where the tooth thickness and addendum depart from the B. and S. standard the formula is—

$$\frac{2\cdot037}{\text{D.P. of block}} - (\text{circular thickness on pitch line} \times 1\cdot9333) - \text{addendum.}$$

Having set the instrument to one block and the dial to zero, the moving jaw is adjusted by the knurled nut till the dial reads the difference required. A chart of differences is provided, of which we reproduce a portion below, so that the complete series within the range of the instrument can be worked to, with a small number of master blocks. The blocks themselves are guaranteed accurate to within ·0003 in., and are actually manufactured to a limit of ·0001 in.

TABLE OF DIFFERENCES AND CONSTANTS.
Brown and Sharpe Standard; Pressure Angle 14½ deg.

$$\text{Thickness} = \frac{\text{C.P.}}{2} = \frac{\pi}{2\ \text{D.P.}} = \frac{\text{Module} \times \pi}{2}$$

$$\text{Addendum} = \text{Module} = \frac{1}{\text{D.P.}} = \frac{\text{C.P.}}{\pi} = 0\cdot3183 \times \text{C.P.}$$

	1 D.P.	3 in.	1½ D.P.	2½ in.	1¼ D.P.	2 in.	1⅛ D.P.
Constants		1·9452	1·6296	1·621	1·358	1·2968	1·1347
3 in.	·0918						
1½ D.P.	·4074	·3156					
2½ in.	·416	·3242	·0086				
1¼ D.P.			·2716	·263			
2 in.			·3328	·3242	·0612		
1⅛ D.P.			·4656	·457	.194	·1328	
1⅛ in.					·2233	·1621	·0293

The outsides of the jaws of the instrument are shaped for the same pressure angle, and by this means uniformity of pitch can be checked as shown in Fig. 3. When used in this way the length included is two tooth spaces and one tooth thickness, the needle being rocked on the central tooth as before. The instrument is not intended for the direct measurement of pitch, but for checking uniformity of division.

The accuracy of involute tooth curves may also be tested, but for this two or three instruments of different pressure angles are required, with the necessary master blocks. The formulæ in this case are somewhat more complicated, and we do not propose to enter further into this point at present except to remark that the method depends upon the fact that normals drawn to the tooth curve at various points up the tooth are all tangents to the base circle, and touch the latter at points which can be determined mathematically, from which fact the proper thickness at the different points up the tooth can be obtained and the instruments set accordingly.

The main function of the instrument is the testing and measurement of gears as they are being cut, but the appliance is useful for other inspection work, and is being employed for testing the wear of teeth in ships' gears, &c., over extended periods. Several vessels now carry one of these instruments, with master blocks, for this purpose. The instrument is one of the most sensitive of its kind, reading variations of tooth thickness of 1/10,000 in., while commercial gears are seldom found to have less inaccuracy than 5/10,000 in.

In conclusion, we may give some figures regarding the accuracy of gears to ensure good running. For automobile work, turbine reduction and other high-class gears the variation shown by the dial should not be more than ·003 in. for gears of less than 6 in. in diameter; not more than ·004 in. for gears between 6 in. and 12 in. in diameter, and ·005 in. for gears between 12 in. and 24 in. in diameter. For gears over 24 in. a variation of ·006 in. should be the limit. The maximum and minimum readings should be in teeth diametrically opposite, the variation between adjacent teeth being little more than appreciable.

SLAG CEMENT MANUFACTURE IN ELECTRIC FURNACES.

THE old-fashioned cement kiln of the shaft type which replaced the original bottle kilns and chamber kilns, has, during the last twenty-five years, had to give way to the rotary kiln, which originated in this country, but had to be developed in the United States before it was adopted in England. Rotary tube kilns were first fired with producer gas. Their usual fuel is now powdered coal, which owes much of its popularity to its efficiency in tubular cement kilns. If electric kilning, now on trial in Sweden, should prove as successful as it promises to do, some kind of shaft kiln may come into use again. The proposal for heating cement furnaces electrically is not new; and if it were simply a question of heat energy the electric kiln would hardly be in a preferential position. Any development will depend upon the combination of two industries, the cement industry and the metallurgical industry, by making cement on the spot where the raw materials of modern cement, slag and limestone, are both available. If the metallurgist can himself make something as valuable as cement out of his slag, instead of sending his slag to the cement manufacturer, a process not looking very tempting in itself may assume a very different aspect.

The experiments to which we refer have for some time been going on in the Domnarfvets Jernverk of the Stora Kopparbergs Bergslags Aktiebolag, in Sweden, and the originator of the process is Mr. K. G. Wennerström, of Oxlösund, to whom we are indebted for

our particulars. Slag, mixed if necessary with limestone or lime, is melted in a cylindrical furnace, lined inside with carbon or graphite. The massive electrode is centrally suspended in the furnace, the dimensions being so chosen that the electric resistance between the electrode and the bottom of the furnace is smaller than the resistance radially between the electrode and the furnace walls. Under those conditions the heat will chiefly be generated below the electrode, and a useful circulation will be set up. With other resistance relations the surface might be overheated. The process has to be conducted so that no electric arc is formed and that the production of calcium carbide is avoided. So far the runs at Domnarfvet have been made with cold slag, *i.e.*, not with the hot liquid slag. If the slag could be charged liquid into the furnace, there to be mixed with lime and to be heated until the mixture has become homogeneous, the process would be cheaper and certain difficulties would be overcome. But others would arise which are now being investigated.

The 3-ton electric furnace at Domnarfvet has a diameter of 2·2 m. (7¼ ft.) and a height of 1·5 m. (5 ft.). Alternating currents of 700 kw. at 60 volts are introduced through one massive electrode, which has a diameter of 0·7 m. (27·5 in.). A run takes about 10 hours. When it is finished the fused clinker or cement is tapped off and a new charge of slag and lime is added. The molten mass is not completely discharged, and the electrode is kept immersed in the liquid mass. The discharged mass is tapped into wagons and spread on a grating. When it contains much lime, it crumbles into a fine flour on exposure to the air; a lump of the size of a fist will do so almost at once, luminescence and heat liberation being observed during the disintegration. Some of the fine powder does not require any grinding; bigger particles are taken to the mill. When the mass is run into water and granulated, grinding is said to be easier than with ordinary heating in tubular kilns. Tests conducted at Domnarfvet show the cement to be of good quality, and to gain in strength on storage. To accelerate the setting a little gypsum is sometimes added to the cement.

The use of the electric furnace makes it possible to prepare highly-calcareous cements subsequently to be blended with other products. The power consumption depends upon the composition of the slag and the quality of the lime, as well as upon the slag temperature. Starting from cold slag the current consumption is high, 1,200 kw. per ton of cement; with hot slag that figure would go down to half its value. The electrode consumption is about 10 mm. of electrode length per run; the thickness of the electrode is also reduced. Slags from alloy furnaces have been utilised, in addition to blast-furnace slags. The slag from ferro-manganese furnaces may contain 10 per cent. of manganese and iron, the latter being mechanically carried rather than chemically bound; the metal collects at the bottom of the cement furnace and is tapped off separately. Granulated slag is also put in the cement furnace. The firm has, further, started a plant for making slag bricks, and seems thus determined to utilise all the by-products of its iron works. These developments are, of course, of greater importance for a country, like Sweden, of dear coal and cheap water power, than for this country. But British metallurgists likewise have to pay attention to the full utilisation of all their by-products and to the restriction of unnecessary transport, and Mr. Wennerström's idea of utilising the distillation residue of oil-shales in cement works may deserve consideration in this connection.

INDUSTRIAL NOTES.

AN interesting table is published by Messrs. Jordan and Sons, Limited, 116 and 117, Chancery-lane, W.C. 2, of the Company Registrations at Somerset House, from January 1 to June 30, 1921. Messrs. Jordan state that the figures show a great decrease in the number of companies registered as compared with the corresponding period of 1920. From their table we select the following classes of companies: Engineers, 3 public and 188 private, total capital, 1,310,990*l.*; iron and brass, 2 and 188, total capital, 2,771,500*l.*; motors, 1 and 140, total capital 1,016,384; oil, 6 and 13, total capital, 5,613,500*l.*; railways, 1 and 2, total capital, 621,000*l.*; shipping, 6 and 96, total capital, 1,769,750*l.*; textiles, 4 and 169, total capital, 4,254,800*l.* The total figures were 204 public and 2,921 private companies, for a total capital of 52,247,158*l.*; as against 878 and 5,537, for a total capital of 448,738,317*l.* in the corresponding period of 1920.

Speaking last week at the conference of the National Union of Railwaymen, Mr. J. H. Thomas said he knew nothing in the railway service to warrant the assumption that there was likely to be a strike in August. In this connection, it is quite reasonable to assume that the success which is surrounding road transport is beginning to act as an eye-opener to the railway world generally.

In a report to the London County Council, the Highways Committee say that the National Joint Industrial Council for the tramways industry have adopted the recommendations of a special joint committee which considered the report of the court of inquiry on the wages of tramway workers. It was recommended that the present rate of wages be maintained until the first full pay period in August; thereafter reductions from and additions to wages are to be at the rate of 1*s.* per week for each complete five points variation either way in the cost of living index figure, starting from the figure of 135 per cent. above the August, 1914, cost of living. Thereafter the adjustment of wages is to be regulated every three months. It is added that a variation of 1*s.* per man per week represents about 31,000*l.* a year in the working of London County Council tramways.

The London Iron and Steel Exchange states that the iron and steel trade have improved but little, and most of the important steel-making works are awaiting a reduction in the price of industrial fuel, the present price, it is alleged, being prohibitive. In some cases it is reported that the steel works which own collieries find it more profitable to sell their coal than to use it in making steel. The recent capture of the Indian Railway contract by British firms is looked upon as a hopeful sign, especially as the low price at which it was booked points to an intention on the part of British manufacturers to seriously meet foreign competition. German producers are, however, securing a considerable share of the Far Eastern and of the South American business which comes on the market, by quoting prices which neither the Belgian nor the French works can approach. The recent firmer tendency of Belgian makers' prices is not being maintained and their quotations have dropped back to the level in force a month ago. The rates quoted by the French works are firmer, and there is less pressure to sell from this quarter. Of the overseas market the most encouraging reports come from Japan, and South Wales works are benefiting by a fair tonnage of orders for galvanised and black sheets.

The engineers' ballot on the reduction of 3*s.* per week of time rates and 7½ per cent. of piece rates on July 15, a similar reduction on August 15, and a joint conference in September to consider the employers' further proposal for the removal of the Ministry of Munitions' bonuses of 12½ and 7½ per cent. on total earnings, gave the following figures: For acceptance, 175,145; against, 108,969, or a majority for acceptance of 66,176. The number of workers affected is over one million, belonging to thirty-three trade unions comprised in the Amalgamated Engineering Union, the Engineering and Shipbuilding Trades' Federation, the National Union of Foundry Workers and the National Federation of General Workers. The above figures show that a very large proportion of the men abstained from voting.

THE SPERRY GYROSCOPIC STABILISER.—In our issue of May 6 last we gave on pages 550 and 556 a description and illustrations of the gyro-wheels forming part of the installation of a Sperry gyroscopic stabiliser which was being built for installation in the American liner Huron, each of these wheels weighing finished 100,000 lb. We now learn that an installation of this kind is to be fitted by the Admiralty to a flotilla leader, and that the equipment will be built in this country by the Metropolitan-Vickers Electrical Company, of Trafford Park, Manchester. The results of this installation will be regarded with much interest. We may add that the photographs of the large rotors which we reproduced on page 556 of our issue of May 6 were taken at the South Bethlehem Works of the Bethlehem Steel Company, Pennsylvania.

ROYAL AERONAUTICAL SOCIETY.—In order to carry into effect the new regulations for the admission of Associate Fellows adopted at the annual general meeting, a syllabus for the candidates' examination has been drawn up and approved by the council. The subjects required, in the first part, are English and either French, German, Italian or Spanish; and in the second part any two of the following: Strength and elasticity of materials and theory of structures, aerodynamics, heat engines, meteorology and navigation, mathematics, and chemistry and metallurgy. For the present, each paper will contain a large number of questions in order to give a wide choice of tests of the candidates' knowledge, and the council have further decided to accept an approved course in aeronautics at a university or technical college as part of the two years' qualifying experience in the application of the science of aeronautics required by the regulations in addition to examination results; in such cases, however, the allowance will not exceed one year. The full syllabus will be published in the forthcoming issue of the Society's Journal, and a list of books recommended for the use of students may be obtained on application to the secretary, whose address is 7, Albemarle-street, London, W. 1.

THE LATE MR. ALBERT CHORLEY ROGERSON.

WE regret to have to announce the sudden death, which occurred on the 10th inst., at Cleveleys, of Mr. Albert Chorley Rogerson, of Malvern, Southport, general manager of Messrs. Beyer, Peacock and Co., Limited, Gorton, Manchester.

Mr. Rogerson was born on June 13, 1869, and was educated at St. Saviour's School, Manchester; he received his scientific training at the Municipal Technical School of the same city. He then served a pupilage of seven years, from 1883 to 1890, with Messrs. Sharp, Stewart and Co., and with the late Mr. Henry Simon. He entered the service of the Lancashire and Yorkshire Railway Company in 1891 and remained with that company until 1902, when he occupied the position of leading and experimental draughtsman. Whilst with the railway company, Mr. Rogerson was engaged under Sir John Aspinall in the designing of locomotives, single and compound stationary engines, and different other classes of machinery, also in the arrangement of plant for engineering workshops and of special tools for locomotive building. He carried out experimental work on train resistance, on the efficiency of steam boilers and superheaters, &c. Mr. Rogerson has written papers on "Superheater and Feed-Water Heaters for Locomotives," "Resistance of Locomotives and Trains," "History of the Lancashire and Yorkshire Railway," "The Advantage and Disadvantage of Superheated Steam," "Coaling of Vessels," "Unloading and Handling Timber from Vessels." He inspected and reported on electro-signalling on the Gand, Bruges and Ecloo Railway, Belgium, and did similar work on railway ticket printing machinery.

In 1903, Mr. Rogerson was appointed works manager to Messrs. Beyer, Peacock and Co., Limited, where he reorganised the whole of the workshops and introduced modern methods of locomotive construction. In 1908, he made a tour of the United States to inspect and report upon machinery, plant and organisation of the principal locomotive, railway shops and locomotive tool manufacturers. He made, in 1909, a tour for the same purpose in Germany, Austria, France, Switzerland and Belgium.

Mr. Rogerson was appointed engineering manager to Messrs. Beyer, Peacock and Co., Limited, in 1910, when he had sole charge of all engineering matters. He carried out further improvements to the works, and instituted the latest locomotive practice. He was also called upon to report on several engineering shops in this country. During the war, his firm undertook large orders for the construction of 5 in., 6 in., 8 in., 9·2 and 18-pounder howitzer equipments, gun tracks, director towers, &c., and under his supervision and to his instructions all the machinery was converted, special jigs, chucks, gauges and new tools designed and made for every type of equipment and for accurate and speedy production. He was appointed general manager of the firm in 1919, when he had complete charge of the whole of their business as locomotive engineers, machine tool builders and steel founders.

Mr. Rogerson was an associate member of the Institution of Civil Engineers since 1902, and a full member since 1920; he was a member of the Institution of Mechanical Engineers since 1908.

He had been in indifferent health for some years past, and shortly after the armistice he had a breakdown from which he never completely recovered. His services to the country during the war were recognised by the award of the C.B.E., but his health had given way under the constant overwork of the war period. He will be greatly missed by all his colleagues and by a wide circle of friends.

NEW PORT TARIFF AT GOTHENBURG.—We read in *Swedish Export* that the Swedish Board of Trade recommends the Government to approve the proposed new port tariff at Gothenburg, which should hold good to the end of 1925, and to grant a rise of 50 per cent. on the tariff during the remaining part of the year 1921.

DIESEL LOCOMOTIVES FOR FACTORY SERVICE.—The firm of Benz and Co., of Mannheim, is putting on the market Diesel locomotives for light and normal gauge tracks, especially intended for factory service. In their general construction the engines resemble the four-cylinder benzine engines which the same firm builds in conjunction with A. Gmeinder and Co., of Mosbach, in Baden. The Diesel locomotives work without compressor, and hence are really semi-Diesels, the fuel being delivered by the fuel pump directly into the cylinder. The engine is started by means of the slightly compressed air stored in a cylinder during the working of the engine; the cylinder is sufficiently large to admit of restarting several times with one charge. The engines are to be constructed without compressor for up to 200 h.p. There are three speeds, and a hauling drum is fitted on one side and a pulley for driving machinery by belting on the other.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Sheffield and German Contracts.—The proposal made by the Electricity Supply Committee of the Sheffield Corporation to buy a German 10,000-kw. generating plant from the Amsterdam Corporation is ruled entirely by price considerations. The corporation was unable to obtain an English quotation anywhere in the region of the Continental offer. The White-Taylor Corporation offered this plant originally built for the Amsterdam Corporation for 49,900*l.* The lowest British quotation was between 90,000*l.* and 100,000*l.* The next lowest was of 80,000*l.* from Switzerland. The proposal resulted in a number of protests being addressed to the Sheffield Corporation, which has now referred the matter back to the Electricity Supply Committee for further consideration.

Iron and Steel.—Judging from the abundance of inquiries received in all branches since the coal settlement, the engineering trades can look to more active conditions. The volume of new business actually booked is not large, but there is every indication that reasonable price adjustments would bring a flood of orders such as would afford an easy approach to normal prosperity. The current rate of production is much below the average, but is improving as coal stocks accumulate. Forges, foundries and rolling mills are re-signing suspended employees so as to get arrears out of hand. Most of the steel furnaces remain idle, and are not likely to be put into regular use until a movement is made towards a reduction in fuel costs. A minor tonnage of acid steel is on order, but business in common steels is exceptionally flat. Blast furnaces occupy a similar position, though the inquiry for foundry iron is gaining in strength. Some makers of engineering tools are worse placed for orders than for many years past. Business in files shows a remarkable shrinkage in certain instances, though other firms have heavy arrears to work off. Trade in saws is equally patchy. One well-known firm is reported to have placed the whole of its remaining employees on notice. The hand-to-mouth business proceeding with Russia affords only slight relief to the agricultural trade. Continental competition in wire rods is keener than ever. Considerations of quality are alone responsible for the few new orders that are being booked.

South Yorkshire Coal Trade.—Householders are buying freely despite the warm weather, and despite the fact that prices are on the up grade. Advances average 2*s.* 6*d.* to 3*s.* per ton, though certain pits are asking as much as 6*s.* per ton above the pre-strike price for pit-head purchase. Merchants are unable to obtain anything like adequate tonnages to meet commitments. A big share of the current output is going to gas and electricity undertakings and railway companies. Engineering establishments are steadily rebuilding stocks, but steel-makers are moving cautiously in the matter of contracts. Their repeated contention is that it is impossible to do business at existing values of fuel. Quotations are irregular and unreliable.

PROPOSED JAPANESE TRUST.—The combination of six private iron and steel companies in Japan is proposed by the Government's Financial and Economic Investigation Committee, as a remedy for the present financial difficulties of the industry in Japan, according to a report prepared by the Far Eastern Division of the Bureau of Foreign and Domestic Commerce, summarised lately in *The Iron Age*. It is suggested that the Japanese Government should give substantial aid to the combined companies, which would have an output about equal to that of the Wakamatsu State Steel Works, while these private plants and the Government works together would control about 90 per cent. of the country's total production.

NEW DINING CARS FOR THE MIDLAND ROUTE TO SCOTLAND.—On Monday last new first and third-class dining cars were put into commission on the Midland and Glasgow and South-Western service between St. Pancras and Glasgow (St. Enoch). The new cars are attached to the 9·35 a.m. from St. Pancras, and the 9.20 a.m. from St. Enoch. The first-class cars are 65 ft. long and run on two six-wheeled bogies. Each car has two dining saloons, capable of seating 22 passengers, kitchen, two pantries, lavatory for staff, luggage locker and lavatory for passengers. The third-class cars are 59 ft. long overall and have two four-wheel bogies. Dining accommodation is for 42 passengers, while there is a luggage locker and lavatory also. These cars are run in connection with the first-class vehicles whose kitchens supply both. The interior decoration is very choice and commendably plain. The woodwork in the first-class cars is walnut and the upholstery in blue cloth. The thirds are furnished in fumed oak with moquette upholstery. The kitchens in the first-class cars are a good deal larger than usual. Each contains a large double oven stove, gas rings for boiling pots, and over these the grills and above these again hot-water boilers. A rapid-heating boiler is also provided for tea. There is also a hot-plate oven. Two large wash-up sinks are provided, refrigerator, &c. The walls of the kitchen are lined with aluminium and the floor with lead sheeting, on which are hard wood grids. The water capacity of the roof tanks is 150 gallons. The gas is carried in two small-diameter cylinders carried on the underframe, and fitted with safety valves. The new cars were built at the Derby works of the Midland Railway to the designs of Mr. R. W. Reid, carriage and wagon superintendent.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—So far as is ascertainable, ironmasters are making no preparations for re-starting blast furnaces to manufacture pig-iron for the open market, declaring that existing conditions will not admit of production on a remunerative business, and the sales that are passing are from stock. The superior qualities of Cleveland pig-iron are now practically unobtainable, but the commoner kinds continue abundant and difficult to dispose of. For this month's delivery to home customers No. 3 G.M.B. is 135*s.*, and purchases cannot be made unless contracts are accompanied with orders for the same quantities of foundry No. 4 at the same figure. The export price of No. 3 and No. 4 foundry is put at 5*s.* above the home quotations. For either home or abroad No. 4 forge and mottled each stand at 117*s.* 6*d.*, and white iron is 115*s.*

Hematite Iron.—Somewhat better inquiry for East Coast hematite is reported, but actual transactions are still few and small. Supply is quite plentiful, stocks of makers, it is understood, being sufficiently large to meet any demand likely to arise. Nos. 1, 2 and 3 are 160*s.* for home use, and 140*s.* for shipment abroad.

Blastfurnacemen's Wages.—The average net selling price of No. 3 Cleveland pig-iron for the second quarter of the year, having been certified at 126*s.* 11·56*d.* per ton, as compared with 198*s.* 1·31*d.* for the previous three months, North-East Coast blastfurnacemen's wages are reduced by 71·25 (71¼) per cent., lowering wages from 144 per cent. above the standard to 72·75 (72¾) per cent. above the standard.

Manufactured Iron and Steel.—In finished iron and steel, manufacturers are anxious to get on with the execution of old contracts, deliveries of which are much overdue, and are recommencing work as fuel supplies come to hand. There is a fair amount of inquiry notwithstanding continued keen Continental competition. Among the principal market quotations are: Common iron bars, 16*l.*; steel billets, 12*l.* 10*s.*; steel boiler plates, 21*l.*; steel ship, bridge and tank plates, 15*l.*; steel angles and joists, 14*l.* 15*s.*; heavy steel rails, 14*l.*; fishplates and sleepers, 19*l.*; black sheets, 19*l.* 10*s.*; and corrugated galvanised sheets, 26*l.*

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Sectional stoppages and accidents are seriously affecting the output of coal. The whole of the collieries controlled by the Ebbw Vale Company and the Tirpentwys Colliery, Pontypool, are idle, as also are the Carngoch and Tirdonkin pits, Swansea, because of disputes between the men and the employers in respect to the withdrawal of certain privileges. An accident to one of the turbines at the power station of the South Wales Electricity Distributing Company at Treforest has also seriously curtailed the production of several collieries which depend on this station for power. In consequence of these troubles the quantity of coal available is insufficient to meet the demand which is especially keen for home consumption. Immediately after the resumption of work in the coalfield prices were on the basis of 45*s.* to 47*s.* 6*d.* for large coal and 25*s.* for best steam smalls, but now many collieries are refusing to give quotations, being already oversold, but middle men holding supplies are asking and obtaining 50*s.* at pit for home consumption and also 50*s.* f.o.b. for export and up to 30*s.* at pit and f.o.b. for smalls. Even at these prices it is practically impossible to obtain supplies. In June only one cargo amounting to 618 tons of coal was exported from South Wales. On the other hand three large cargoes of American coal have been directly imported during the past week and one cargo of Belgian coal. The American cargoes amount to 22,964 tons, and are intended for the Great Western Railway Company, while the Belgian cargo of 1,300 tons is for the Aberthaw Cement Company. In all, eight cargoes of 27,532 tons of American and Continental coal have been directly imported into South Wales during the past month. The make of patent fuel is restricted by the shortage of small coal, but for the small quantity available sellers are asking from 42*s.* 6*d.* to 47*s.* 6*d.*, according to quality. The coke market is idle. So far only one company has restarted its ovens, and as the make is only sufficient to meet the company's own requirements there is practically nothing left for disposal. Business has, however, been transacted for August delivery of foundry coke at 67*s.* 6*d.* at ovens, while for export quotations are nominal at 60*s.* to 65*s.* f.o.b.

The Iron and Steel Trades.—Though coal is gradually finding its way to the works business remains inactive in consequence of a lack of orders. At present only about 10 per cent. of the mills are operating. About 95 per cent. of the Welsh works are associated with the Welsh steel bar trade, and this militates against the use of foreign bars, and it is argued that Welsh steel prices must come down if tin plates are to be cheaper. For standard sizes of tin plates quotations are nominal round 27*s.* 6*d.* per box for prompt delivery, while for forward business 24*s.* to 24*s.* 6*d.* is asked compared with 25*s.* a week ago.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

State of Trade.—In many branches of industry there has been no movement yet, although in a certain number a moderate start has been effected. All over, however, it is a generally accepted idea that it will be well into the month of September before we see a decided decrease in unemployment. In the iron, steel and allied industries the fuel question is the all-important thing, and the moment prices become reasonable trade will begin to get brighter. The outlook in the shipbuilding industry is very dull indeed and a dark autumn is anticipated. Export all round is very poor.

Scottish Steel Trade.—The state of things in the Scottish steel trade has not improved and no change can be reported. There is a great desire all round, both on the part of the employers and the workers, to get a move on, but so long as fuel remains in the region of prices which rule to-day, little or nothing can be done, because, after all, the steel producer, like the miner, wants profitable business. Supplies of coal are certainly improving, but the prices asked are prohibitive from the manufacturing point of view, particularly when the foreigner can offer his goods in this country at so much less than the home producer is able to sell. We are told that this will all come right in time, but a drastic cut is absolutely necessary at once to enable the industry of the country to get on to its feet, as it were. Inquiries of one kind and another are floating around, but actual business is of little note. Prices are unchanged.

Scottish Malleable Iron Trade.—In the malleable iron trade of the West of Scotland there is very little doing and conditions do not look over bright. At to-day's price of coal the competition with the Continent cannot be faced, and although the price of "crown" bars was lately reduced to 16*l.* per ton, there has been little response on the part of buyers. Order books are pretty bare at the moment, and unless a lot more business is forthcoming a general re-start of the works will be delayed for some time.

Scottish Pig-Iron Trade.—Conditions in the pig-iron trade of Scotland have not improved, and the outlook is far from encouraging. Stocks are being depleted by those consumers who have made a start, and it is difficult to see when producers will commence to smelt again and have more iron to offer. In the case of foundry iron the prospects are getting serious as stocks have now almost reached vanishing point, but of hematite there is still a fair amount available.

Annual Holidays.—With the close of the annual summer holiday period on the lower reaches of the Clyde, that of the upper part—Glasgow and the Motherwell districts—has started. Work will cease to-morrow or Friday in those establishments which have been in operation, but many of the engineering shops have already closed down, and a resumption will not be general until Monday, 25th, or Tuesday, 26th inst. By that time it is hoped that fuel will be more plentiful and a bit cheaper, and so enable trade to pick up.

THE "ELOY" PNEUMATIC HAMMER.—We are asked by Messrs. Mossay and Co., Limited, of 7, Princes-street, Westminster, to mention that the pneumatic hammers described in our issue of June 24, page 775, are manufactured, under the above name, by Messrs. Reavell and Co., Limited, of Ipswich, for the Reavell-Mossay Pneumatic Tool Company, who hold the licence from the patentees, and who have appointed Messrs. Mossay and Co. as selling agents. The latest list of these hammers states that a ½ rivet can be closed in 4½ secs. with an expenditure of 1·75 cub. ft. of free air by a hammer weighing 13·25 lbs.; a ⅞ rivet can be closed in 5½ secs. with an expenditure of 2·25 cub. ft. of air by a 17-lb. hammer, and an inch rivet can be closed in 6½ secs. for 3·25 cub. ft. of air, the hammer in this case weighing 22½ lbs.

FOREIGN FIRMS IN CHINA.—According to the Chinese Government Bureau of Economic Information, foreign firms in China are increasing rapidly. The latest report shows the following:—

	Firms.	Personnel.
U.S.A.	413	6,660
Belgium	20	391
Denmark	27	546
Austria	5	27
Great Britain	644	13,234
Netherlands	25	367
France	171	4,409
Germany	2	1,235
Italy	19	376
Japan	4,878	171,485
Norway	12	249
Portugal	93	2,300
Russia	1,780	148,170
Spain	8	272
Switzerland	4	632
Others, unclassified ...	33	537

PERSONAL.—Mr. A. Bornemann, a director of Messrs. Ruston and Hornsby, Limited, has been appointed a Commander of the Order of the British Empire, for services rendered to the Ministry of Munitions during the war.—Messrs. Robert Stephenson and Co., Limited, Darlington, state that their London address is now 17, Victoria-street, Westminster, S.W.1.—In consequence of the retirement of Mr. William Willox, the directors of the Metropolitan Railway have appointed Mr. Edward A. Wilson, M.Inst. C.E., to the position of chief civil engineer to the company. Mr. C. W. Clark, A.R.I.B.A., has been appointed architect to the company. The Civil Engineering and Contracting Department of Sir W. G. Armstrong, Whitworth and Co., Limited, has now removed to offices at 51, Victoria-street, Westminster, S.W. 1. (Telegraphic address, "Ubiquity, Vic, London"; Telephone Nos., Victoria 1761 and 1762.) The hydro-electric section will remain at 8, Great George-street, Westminster.

THE TURBINE-DRIVEN QUADRUPLE-SCREW TRANSATLANTIC LINER "PARIS."

CONSTRUCTED BY THE SOCIÉTÉ ANONYME DES CHANTIER ET ATELIERS DE ST. NAZAIRE.

(*For Description, see Page* 96.)

FIG. 10. FIRST-CLASS DINING-SALOON.

FIG. 11. FIRST-CLASS DRAWING-ROOM.

AGENTS FOR "ENGINEERING."

AUSTRALIA: Gordon and Gotch, Limited, Melbourne; Sydney; Brisbane; Perth. Angus and Robertson, Limited, Sydney, N.S.W. T. Willmett and Co., Townsville, North Queensland. W. C. Rigby, Adelaide, South Australia. Melville and Mullen, Melbourne, Victoria.
BELGIUM, Brussels: H. F. Satchell, 88, Rue du Tabellion.
CANADA, Toronto, Ont.: Wm. Dawson and Sons, Ltd., 67, Queen Street East.
EDINBURGH: John Menzies and Co., 12, Hanover-street.
FRANCE, Paris: Boyveau and Chevillet, 22, Rue de la Banque.
For Advertisements, Agence Havas, 8, Place de la Bourse.
GLASGOW: William Love.
INDIA, Calcutta: Thacker, Spink, and Co., Bombay: Thacker and Co., Limited.
ITALY: U. Hoepli, Milan.
Anonima Libraria Italiana, Torino.
And any post office.
LIVERPOOL: Mrs. Taylor, Landing Stages.
MANCHESTER: John Heywood, 143, Deansgate.
NEW ZEALAND: Gordon and Gotch Proprietary, Limited, Wellington, Auckland and Christchurch.
NORWAY, Christiania: Cammermeyer's Boghandel, Carl Johans Gade, 41 and 43.
ROTTERDAM: H. A. Kramer and Son.
SOUTH AFRICA: Central News Agency, Limited, Head Office—Johannesburg; and Pretoria, Cape Town, Port Elizabeth, Bloemfontein, Durban, and their various branches and bookstalls throughout South Africa. Also Wm. Dawson and Sons (South Africa) Ltd., 29 and 31, Long Street, Capetown.
TASMANIA: Gordon and Gotch Proprietary, Limited, Launceston: Hobart.
UNITED STATES: For Subscriptions, New York: W. H. Wiley, 432, Fourth Avenue.
For Advertisements, J. S. Allan, 30, Church-street, New York.

ADVERTISEMENT RATES.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12s. per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

SUBSCRIPTIONS, HOME AND FOREIGN.

REVISED RATES.

"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

For the United Kingdom	£3	5	0
For Canada—			
Thin paper copies	£2	18	6
Thick paper copies	£3	3	0
For all other places abroad—			
Thin paper copies	£3	3	0
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With a Two-Page Plate of the TURBINE-DRIVEN QUADRUPLE-SCREW TRANSATLANTIC LINER "PARIS."

ENGINEERING.

FRIDAY, JULY 15, 1921.

WHAT NATIONAL BANKRUPTCY WOULD REALLY MEAN.

A GREAT deal has been said lately as to the necessity for reducing the national expenditure and for increasing production as the only alternative to "National Bankruptcy." No one, however, appears to have explained what national bankruptcy would really mean, and the term is used probably mainly as a sort of threat. In fact, the large majority of people probably feel that it will not take place and that in any case people manage to get fed and clothed in these days. Many think that at the worst it can only mean going to the Government for some more money for unemployment benefit and that we shall at all events muddle through all right. It may therefore be worth while to see whether it really is impossible for something like national bankruptcy to take place and what would be the effect of it if it did happen.

The revenue of the country must, of course, come from its resources, and these are essentially of three kinds. First there is the active production of the country, that is to say, agricultural produce and the outputs of our various mines, factories, &c. Second there is the interest on foreign investments, including the management expenses of businesses having their headquarters in England while their productive part is abroad. Third there is the profit from trading in foreign products.

With regard to the first the position is simple. It is obvious that the result of any productive business can only be the value of the products. If, for instance, the value of the products of any farm averages 1,000*l.* a year, this is the maximum amount which can be divided among the various people dependent on it, whether they are direct employees or the tradesmen dependent on supplying goods either to the farm or those employed on it, &c. The total taxes which can be collected from the produce of this farm, whether in the form of direct taxes on the farmer or indirect taxes on the goods consumed by him or his employees, &c., can only be a certain proportion of the 1,000*l.* If, either through high taxes or high costs of other kinds, the cost of producing the goods which sell at 1,000*l.* gets too high, the farm just goes out of cultivation and produces nothing, and of course ceases to give employment or to pay taxes at all. What is true of a small business such as a very small farm is true of any other productive one, however large.

It may here be observed that the amount of taxation paid by productive businesses is a good deal greater than is generally realised. There is, of course, first the direct taxation, such as income tax. There are also the various taxes on those directly employed by the firm, such as their income taxes and the various taxes on the dutiable goods they buy, such as tea, tobacco, &c. There are the taxes on the houses they live in. In addition there are many people, such as tradesmen, who are largely dependent on the employees of the firm, and a large share of the taxes paid by these come indirectly from the same source. In fact, a large firm has a number of dependents directly and indirectly living on it, and if it shuts up and no other firm takes its place it means a very large loss of revenue in addition to that paid directly by the firm itself.

In the case of such a simple industry as a farm the production is practically the sole issue. In many of our businesses, however, the matter is not so simple. Thus where very large quantities of goods are bought abroad and a certain amount of manufacturing is done on them, and they are then exported, the profit may be not by any means solely due to production, but quite a large proportion may be really due to simple trading, i.e., buying at one price and selling at a higher.

A very considerable part of our population and of our revenue is, undoubtedly, dependent simply on foreign trading, finance and investment. It is common knowledge that there are an enormous number of concerns with offices here which have their productive activities abroad. Instances of these are various rubber and oil companies, foreign mines and other enterprises too numerous to enumerate. Moreover, a considerable number of the productive businesses here have branches abroad. There are also a number of people living here who have the bulk of their money invested in foreign securities and live on the interest. Then there are various firms devoted to foreign banking and finance, and also firms who do trading all over the world in various goods which never come to England.

A very considerable amount of our revenue comes from these various foreign activities. Not only is there the direct income tax on the income derived from the foreign investments and the profit on the concerns which have their productive capacity abroad, but there are the various direct and indirect taxes paid by the employees, &c. Many of the clerks in the city, for instance, are employed in the offices of such firms, while solicitors, bankers, &c., get a good deal of their business from them. Further, all these various people, from the wealthy magnate to the poor clerk spend their money in this country and keep various other trades going. Hence quite a large part of our revenue comes directly or indirectly from these sources.

Now let us see what will happen if the expenditure of the country exceeds the revenue which it can really afford to pay. Naturally the first thing will be that those who have their money invested abroad will go and live abroad, and the revenue from their income tax and the various indirect taxes will be lost. Also as they cease to spend their money in the country a certain number of people will be thrown out of employment. Next, the various firms whose productive work is abroad, but who have offices here, will shift their offices. By doing so they will cease to employ their clerical staff here.

This tendency would have a serious effect on our manufactures for the very fact that foreign concerns have their offices here brings us a considerable amount of work. Once these firms shifted their offices abroad our manufacturers would find it very much more difficult to get orders from them.

An emigration of those interested in foreign business would therefore entail a very serious loss of revenue. If the revenue were to meet the expenditure extra taxation on the various businesses producing in this country would then have to be imposed. But if the production is overtaxed it will fail to be profitable, and in this case will not attract capital, and without capital it will gradually die out. Those who have any money will simply invest it elsewhere, and as plant, mines, buildings, &c., are worked out they will be abandoned. What then?

If this actually happens there will be a terrible catastrophe. England does not grow anything like enough food for the whole of its population, and in order to grow what it does requires capital in agriculture. No one will send us food unless we can give them something in exchange. Government assistance would be impossible, for the Government would already be in a position of insolvency, and no one would have any money to lend it. It would be no use trying to pay for food with paper money, for the paper of an insolvent Government is valueless.

Obviously the country would sink back into the same primitive position as other islands of the same size, which have no important trade or manufactures. Labour would, of course, rapidly fall in price and in this case it would pay to employ more people in agriculture and use more primitive plant. We should have, therefore, a primitive agricultural population living on its own produce, and in this way no doubt a good many millions could live here, though at a very much lower standard than they do now. Many millions would, however, have to emigrate or starve. Those who were at all rich would, of course, have little difficulty, but to the bulk of the poor emigration would be impracticable. Undoubtedly many millions would starve. It may be thought that such a catastrophe is impossible, but such things have happened before, even in quite modern times, and not very far away.

Famines, which are really simply the expression of national bankruptcy, have swept out quite large proportions of various populations from time immemorial. Coming to recent times we may take

the case of the Soudan under the Mahdi. This leader proclaimed a Holy War, and gathered the bulk of the population to go and fight, promising them victory and plenty. As a result production to a large extent ceased, and when the current stocks of food were exhausted there was no food nor anything which could be sold to buy food. Famine produced disease and a very large part of the population died. It is not possible to get accurate returns of the deaths during the period of the Mahdi's rule, but certain authorities put the loss of life at something like 30,000,000 people in a few years. It is undoubted that it was enormous, and that very large tracts of country went out of cultivation because they were not wanted.

Much nearer home, and not very long ago historically, we may take the Irish famine of about 1848. Here the essential cause of the failure of production was the potato disease which interfered with the one real productive business of the country. Again it is impossible to get quite accurate numbers, but the population had grown from 7,767,401 in 1831 to 8,175,124 in 1841. In 1851 it was only 6,552,385, so allowing for the normal increase it appears that about 2,000,000 people died from the results of the famine. A certain number of others doubtless emigrated, but facilities for emigration were very small in 1848. It will perhaps be easier to realise the extent of this disaster if we say that the percentage of loss of the population was about twelve times as great as our losses in killed in action and through disease in the late war, and that the actual number who died was about three times as great.

These matters should be very seriously considered at the present time by the various leaders of the country, whether members of the Government, employers, labour leaders or others with influence. There is no doubt that it is perfectly possible to make the country not only solvent but extremely prosperous. In order to do so we must, however, reduce our expenditure very greatly indeed, and also largely extend our production. With a big production and a reduced expenditure taxes could be very greatly lowered and yet the needful revenue obtained and lowered taxes would allow us to compete in the world's markets and get plenty of work for our population. But if excessive taxation is maintained and production not increased the various business men will begin shifting their businesses and this will cause a decline of revenue. Once this seriously starts it will be very difficult to stop, as increase of taxation to make the revenue meet the expenditure will only accelerate the shifting of capital and therefore the final downthrow.

CLAIMS BEFORE THE WAR COMPENSATION COURT.

Of the manufacturers whose premises were taken over by the Government during the war a large number have by this time obtained compensation for the loss which they have suffered; but it may be well to remind those whose claims are still outstanding of the existence and powers of the War Compensation Court, which was brought into being by the Indemnity Act, 1920. The Court, which is presided over by a judge of the High Court, takes the place of the tribunal formerly known as the Defence of the Realm Losses Commission. It may compel witnesses to appear before it. There is no appeal from its decisions except on a point of law.

There are two reasons why we desire to draw attention to this tribunal. In the first place those who desire to prefer claims should waste no time in the matter, for by s. 2 (1) (*b*) (ii) notice of the claim must be given to the tribunal in such form and manner as the tribunal may prescribe within one year from the *termination of the war*, or the date when the transaction giving rise to the claim took place, whichever may be the later. Although the war is not technically yet at an end, it is obvious that the sooner a claim is preferred, the sooner it will be dealt with. Another reason for drawing attention to this Court is that apart from the fact that a list of the cases to be considered is published daily in the press, the public knows very little about it. The hearings take place in private, although there is nothing in the Indemnity Act, 1920, to prohibit public sittings. The amount awarded is never published except to the parties; and no reason is given for the decision. If a claim for £10,000 is preferred the sum of £1,000 may be awarded without the reduction being explained in any way. Again, although the claimant may have been put to considerable expense in preparing his case, he will only be awarded a small sum on account of costs. The reasonable expenses of witnesses who attend are, however, paid in full.

The principle on which claims are, or ought to be dealt with, is thus stated in a schedule to the Indemnity Act: "The compensation to be awarded shall be assessed by taking into account only the direct loss and damage suffered by the claimant by reason of direct and particular interference with his property or business, and nothing shall be included in respect of any loss or damage due to or arising through the enforcement of any order or regulation of general or local application, or in respect of any loss or damage due simply and solely to the existence of a state of war, or to the general conditions prevailing in the locality, or to action taken upon grounds arising out of the conduct of the claimant himself rendering it necessary for public security that his legal rights should be infringed, or in respect of loss of mere pleasure and amenity."

So far as the writer is aware, no case has yet reached the Court of Appeal which sheds any light upon the meaning of the above words. One has to go back to first principles in order to interpret them. Disregarding the proviso to the schedule, let us consider the question. What is included in the words "direct loss and damage suffered . . . . by reason of direct and particular interference with his property or business?" It is difficult to say precisely what will be taken into account, but it is plain that on one reading of the words, a claimant might well say: "I am entitled to be indemnified in respect of any loss which I actually suffered as a result of my property being taken." The writer, however, happens to have been informed of the facts in one case which seems to show that a full indemnity will not be granted. Owing to the exigencies of the military situation it became necessary for the War Office to take over and pull down a certain factory. Everything had to be done in a hurry, but before the military authorities actually entered into possession the owner had time to employ an engineer to examine the building and fixed machinery as it then existed so that when reinstatement became possible everything might be restored to its former condition. Subsequently the military took over the factory, pulled it down, and after about two years the Government department concerned intimated that they were ready to give up possession. They offered to reinstate but the offer, which was gladly accepted by the owner, was subsequently withdrawn owing to the lack of men to do the work. Anxious to resume his business as soon as possible, the owner then procured estimates from various builders. Having seen these estimates the Government offered a certain sum which was considerably less than the lowest estimate, in full settlement. The owner refused to accept this offer, but proceeded to employ the builder who gave the lowest estimate to carry out the work. When everything was finished he claimed the full amount of the estimate, together with certain extras which had been occasioned by the rise in price of materials and increased cost of labour. His claim was referred to the War Compensation Court. That the work had been done and the money expended was practically admitted; but the point was made on behalf of the Government that if the building had been done earlier it would have cost less.

In the result, the Court awarded the claimant a lump sum, which was practically the mean between the amount which he had actually expended and the sum which had originally been offered by the War Office. Whether this rough and ready method of doing justice was adopted by the Court, either on principle or otherwise there is no means of knowing, because no reasoned judgment was delivered; but the fact remains that the claimant was awarded very much less than he had actually expended in reinstating his premises. Incidentally it may be mentioned that he had made no claim for loss of business during the period whilst he was out of possession.

As regards its procedure the War Compensation Court follows that which is adopted in the High Court. The claimant states his case either in person or by counsel or solicitor, and then calls his witnesses. The ordinary rules of evidence are observed, but are enforced with rather less rigour than on ordinary courts of justice, documents and plans being generally accepted although they are liable to be objected to if they are not strictly proved. Witnesses may be subjected to cross examination by counsel on behalf of the Crown. As already intimated, no formal judgment is pronounced, the decision of the Court being announced privately to the parties concerned.

From the instance above given it would appear that a claimant must not expect to get all he asks for; but it has always to be remembered that by reason of the Indemnity Act, 1920, thousands of people whose property was taken during the war are in a much better position than they were under the law as previously administered. Besides, if it were to be known that the War Compensation Court would always indemnify, the natural tendency to exaggerate a claim for loss might be seriously increased.

MERCHANT SHIPBUILDING.

The condition of the shipbuilding industry as revealed by the returns just issued by Lloyd's Register for the June quarter is very similar to that explained on page 495 of our last volume, when dealing with the figures for the March quarter. The tonnage in hand, 3,530,047, is still very high, although it is 268,000 tons less than at the end of the March quarter, and 48,000 tons less than was building at this time last year; but the figure given by no means represents the work actually in progress. Work has, in fact, been entirely suspended on 735,000 tons of shipping nominally "under construction," and the completion of a further 444,000 tons has been postponed, mainly on account of the joiners' strike and the coal dispute. Subtracting these two totals from the figure given above leaves 2,351,047 tons actually building, and this compares very unfavourably with the figure of 3,578,153 tons in hand at the end of the June quarter of last year.

Of even greater significance, with respect to the immediate future of the industry, is the fact that only 23 vessels, with a total tonnage of 69,028, have been commenced during the quarter, this tonnage being less than 2 per cent. of that in hand at the beginning of the quarter. The tonnage commenced, it may be added, has progressively diminished since the September quarter of last year, during which quarter 170 vessels making 593,821 tons, were put in hand, while the corresponding figures for the December and March quarters were 506,353 tons (148 vessels) and 392,877 tons (99 vessels) respectively. The tonnage of vessels launched has also diminished, although the drop for the June quarter is not so marked as in the case of the tonnage commenced. In the June quarter 100 vessels, making 321,690 tons, were launched, as compared with 131 vessels, making 433,607 tons, in the March quarter and 176 vessels, making 579,933 tons, in the December quarter.

The tonnage of 3,530,047, which is now under construction with the reservations explained above, is comprised in 789 vessels, of which 715, with an aggregate tonnage of 3,284,912, are steamers. Of the remainder, 57, totalling 241,003 tons, are motor vessels, while the other 17, which make only 4,132 tons, are sailing ships. Of the steamers building, 63 are of 10,000 tons or over, 6 coming between 10,000 tons and 12,000 tons, 27 between 12,000 tons and 15,000 tons, 24 between 15,000 tons and 20,000 tons, and 5 between 20,000 tons and 25,000 tons, while 1 is of over 25,000 tons. It may also be of interest to mention that 89 steamers and motor vessels, of 1,000 tons and over, are being built in this country for the carriage of oil in bulk. These vessels have an aggregate tonnage of 585,980, which represents about 16½ per cent. of the total tonnage building in the United Kingdom. A large number of vessels are also being built in this country for foreign owners, the number being 202 and the

tonnage 978,752, or nearly 28 per cent. of the total. Our principal customers are France, Norway and Holland, for which countries the tonnages under construction are 253,883, 201,663 and 189,916, respectively.

As might be expected from the figures given above, the work in hand at all the large shipbuilding centres has declined during the quarter. At Glasgow the drop is from 1,009,277 tons in hand at the end of March to 953,978 tons in hand on June 30—a decline of 5½ per cent. At Greenock the reduction has been proportionally greater, the figures being 292,530 tons in June, as compared with 336,587 tons in March, the drop in this case being about 13 per cent. The Newcastle district, which is the second largest shipbuilding centre in the country, appears to have suffered rather less than the Clyde, since the reduction in work at the former is only a little more than 4 per cent. The June figure for Newcastle is 680,334 tons, while that for March was 710,752 tons. The work in hand at Belfast, however, has declined during the quarter from 411,180 tons to 356,150 tons—about 13½ per cent. At Sunderland the work in hand now amounts to 328,488 tons, as compared with 339,375 tons at the end of March, a drop of just over 3 per cent.; while at Middlesbrough, which includes Stockton and Whitby, the reduction amounts to nearly 8 per cent., the tonnage in hand having fallen from 231,181 to 213,258 during the period under consideration. The only other districts having more than 100,000 tons of shipping under construction are Liverpool and Barrow, the figure for the former port being 114,925 tons at the end of June, which is only 1·7 per cent. less than the corresponding figure for March, which was 116,969 tons. The figure for Barrow, however, shows a reduction of over 20 per cent., the work in hand now being 108,349 tons, as against 136,918 tons for the March quarter. At Hartlepool a proportionally large reduction in shipbuilding work has also occurred, the figure of 106,300 tons for the end of March having fallen to 89,965 tons at the present time; the drop is thus about 15½ per cent. The figures for the remaining districts of the United Kingdom for the end of the June quarter are as follow: Dundee, 78,840 tons; Hull, 68,414 tons; Southampton, 61,509 tons; Leith, 50,558 tons; Londonderry, 24,800 tons; Aberdeen, 18,605 tons; Newport (Mon.), 17,804 tons; and Dublin, 13,245 tons. In all cases except those of Dundee, Leith and Newport, for which increases are recorded, the figures given are less than those for the end of the March quarter.

Excluding Germany, for which country figures are not yet available, the number of merchant vessels now under construction abroad number 851 and have a total tonnage of 2,669,421. The latter figure is less by about 619,000 tons than that for the end of March, the reduction being largely due to the continued decrease in shipbuilding work in the United States. That country, it may be mentioned, is now building only about 17 per cent. of the tonnage under construction in March, 1919. The figures for foreign shipbuilding, however, are not subject to any material reductions on account of suspended or delayed work, such as are necessary in comparing current statistics for the United Kingdom with those for previous periods.

In spite of the reduction above referred to the United States still holds the first position among foreign shipbuilding nations, having 102 vessels in hand with an aggregate tonnage of 717,624. From the point of view of tonnage building, Holland takes second place, with France a close third, the respective figures for these two countries being 391,389 tons (155 ships) and 390,453 tons (105 ships). Italy follows with 128 vessels, making 310,333 tons, in hand, while Japan takes fifth place with 45 ships, having an aggregate tonnage of 229,262, under construction. Collectively, the British Dominions come next in order of magnitude of shipbuilding work in hand, having, in all, 62 vessels, with a total tonnage of 177,912, now in progress. More than half of these (33 vessels, making 94,123 tons, to be exact) are building in Canada, mostly in coast yards, but 2 vessels, of 4,803 tons together, are building on the Great Lakes. At Hong Kong, 14 ships, with a total tonnage of 50,560, are under construction, while Australia is building a further 11 vessels totalling 30,379 tons. Four more ships, with an aggregate tonnage of 2,850 are accounted for by other British Dominions. Among the Scandinavian nations Denmark now takes first place in the matter of shipbuilding work, having 43 ships, making 109,410 tons, in hand, as compared with 97,547 tons (44 ships) in hand in Sweden and 85,374 tons (59 ships) building in Norway. The only other countries with more than 10,000 tons of shipping in hand are Spain (18 ships, 80,067 tons), China (7 ships, 24,698 tons), Belgium (7 ships, 23,165 tons) and Portugal (40 ships, 15,223 tons).

Of the vessels building abroad, 126, with a total tonnage of 261,941, are classed as motor vessels, so that adding to these the 57 motor vessels, making 241,003 tons, building in this country, we get a total number of 183 and an aggregate tonnage of 502,944 under construction in different parts of the world. This tonnage, it is interesting to note, is more than 8 per cent. of the world's total tonnage building, while the corresponding figure for sailing ships is less than 1 per cent. We may also add that, of the vessels building abroad, 79 steamers and motor ships, of 1,000 tons and over, are intended to carry oil in bulk. Of these vessels, which make 565,598 tons together, 48, with an aggregate tonnage of 388,868, are building in the United States, and 8, making 58,980 tons, are being built in France. The oil-carrying vessels now under construction in the world thus number 168 in all, and their aggregate tonnage, of 1,151,578, represents about 18½ per cent. of the total tonnage building.

In conclusion we may perhaps remind our readers that the tonnage figures given above are the gross tonnages in each case, and that Lloyd's statistics do not take account of vessels of less than 100 gross tons.

NOTES.

The New King George V. Dock.

On Friday last, July 8, Their Majesties the King and Queen, accompanied by other members of the Royal Family, visited and formally opened the new dock which we described in our issue of July 1. This important addition to the dock accommodation of the Port of London, which has hitherto been known as the Royal Albert Dock Extension (South) was re-named by His Majesty, and will henceforth be known as the King George V. Dock. The ceremony, which was attended by a large number of guests of the Port of London Authority, was a distinct success, being favoured with ideal weather. An address was read by the Chairman of the Port of London Authority, Lord Devonport, and in reply the King, after referring to the development of the port in the past, and to the connection of many of its large works with names of the Royal Family, said he hoped that day would be a landmark in its history, and complimented the Authority on the enterprise it had shown since its inauguration in 1908. The new dock was so fully described in our issue of July 1 that we need not revert to details of the work. We may state, however, that the water area of the docks now owned and worked by the Port Authority amounts to 704 acres, the latest addition being responsible for 64. The new dock is not by any means the largest in area, but with its great depth will allow vessels of 30,000 tons to be berthed within about 6 miles of the city, while its long quayage provides berthing accommodation for quite a number of such vessels. During the ceremony on Friday last, Mr. F. Palmer, M.Inst.C.E., formerly chief engineer to the Port Authority; Mr. C. R. S. Kirkpatrick, M.Inst.C.E., the present chief engineer; and Mr. A. Binns, M.Inst.C.E., resident engineer during construction of the new dock, together with others, were presented to Their Majesties.

Coastwise Shipping and Exceptional Rates.

The coastal shipping trade is, like many other trades, in an exceedingly precarious position, more than half the coastal vessels being laid up in port, and most of the rest only working because the losses by so doing are less than those incurred by idleness. Representatives of the coastal trade have recently placed the facts before the Rates Advisory Committee of the Ministry of Transport with a view to urging that the railway companies should be prohibited by statute from granting any exceptional rates for merchandise which are more than 20 per cent. below the class rates. It was shown by the shipowners that before the war they could carry cocoa between Bristol and London for 16*s.* 7*d.* per ton, which was made up of a shipping rate of 8*s.* 4*d.* and terminal charges of 8*s.* 3*d.* The present terminal charges alone amount to 32*s.* 2*d.*, and as the railways quote a rate of 38*s.* 8*d.* for this traffic, the shipowners, to compete, would have to carry the goods at much less than the pre-war rate, although their own expenses are several times greater than before the war. On behalf of the railways, it was maintained that the exceptional rates are profitable ones to themselves, and any compulsory increase would be unfair both to themselves and to traders generally. The Advisory Committee find that it would be impracticable to make any such enactment as the shipowners ask for. They report that the true remedy is to reduce shipping costs, and terminal expenses in particular, as "these swollen costs are killing the business, and, in the interests of all concerned, economy in expenditure is essential, even if it has to be effected by reductions in wages. It would, however, be far better if the reduction were brought about by more work being done for the day's wage than by lowering the actual wage." As figures in the report show that it costs five times as much per ton to collect goods in London as it did before the war, there is surely something to be done in this direction. The complete report is issued as a White Paper and may be obtained at the price of 1*d.* at H.M. Stationery Office.

Explosives in 1920.

The report of His Majesty's Inspectors of Explosives for the year 1920 shows that fewer factories are now being used for manufacturing explosives than was the case in pre-war times. This reduction is mainly due to the amalgamation of the principal firms into one undertaking and a consequent surrender of licences. The total accidents are somewhat below the pre-war level and, as usual, most of the accidents have occurred in the storage or use of explosives and not in the process of manufacture. In short, accidents in factories numbered 44 out of a total of 455, and caused 2 fatalities out of a total of 50. Very few of the accidents in use, appear to have been due to faulty explosives, but were almost wholly attributable to rashness or slackness on the part of the users. Out of a total of 361 accidents in the use of explosives, 29 were due to men failing to get away in time. A failure which in some cases was no doubt due to prematures. There were 9 accidents due to unexploded cartridges being found amongst the *debris*, and 6 were due to misfires. All or some of these may have been due to faulty materials, but the remainder had other causes. In one remarkable accident, 250 tons of therm-alloy, an incendiary mixture, were ignited, and the fire spread to a very large number of safety cartridges stored near by. Seven men suffered from burns, and one of these was seriously injured, but all had a wonderful escape. Some experiments with liquid air explosives were carried out during the year in the presence of the Government inspectors, by the Liquid Air and Rescue Syndicate, Limited, and the results are stated to have been satisfactory. The cartridges were made of paper, and were filled with a carbonaceous material. Before using they were soaked in liquid air containing 80 per cent. oxygen for 15 minutes, and were then charged into the holes, being stemmed in the usual way. The shots were fired by electricity. Two new explosives have been added during the year to the list of those permitted in coal mines, viz., super-excellite No. 4 and monarkite.

"Paragon" Super-Diesel Internal-Combustion Engine: Erratum.—In our report (page 72 *ante*) of the discussion on the paper by Mr. A. E. L. Chorlton, on "Super-Compression for Internal-Combustion Engines," read before the recent Conference of the Institution of Mechanical Engineers, we stated that Captain W. P. Durtnall referred to an engine which he was developing specially for locomotive work, to burn paraffin. Captain Durtnall writes to us, in connection with this new "Paragon" cycle engine, to say that: "Although we have experimented with this improved heat cycle with engines operating on petrol and paraffin, the locomotive engine referred to is for operation on Admiralty fuel oil, and not on costly paraffin."

LITERATURE.

The Air Supply to Boiler Rooms of Modern Ships of War. By RICHARD W. ALLEN, M.Inst.C.E., M.I.Mech.E. Second edition, 1921. London: Charles Griffin and Co., Limited. [Price 42*s.* net.]

IN considering the enormous concentrations of power which are typical of modern battleships or central stations, one is apt to forget the corresponding magnitude of the auxiliary machinery upon which the proper functioning of the main units depends. The capacity of the latter is the figure which seizes the imagination, and the adequacy of the auxiliaries is taken for granted, although the engineering problems which they involve may be quite as difficult as those which confront the designer of the prime movers. In a modern battleship such as H.M.S. Hood, in which the main turbines are rated at 140,000 h.p., the boilers may easily be called on to burn oil at the rate of 150,000 lb. per hour, and to do this air must be delivered to the furnaces at the rate of 723,000 cub. ft., equivalent to about 55,000 lb. weight per minute. These figures give some idea of the magnitude of the fan installation alone, and when it is realised that all this vast quantity of air has to be collected by suitable intakes on the deck, led through air trunks to the fans and then delivered to the stokeholds in such a way that every furnace gets its proper supply, it will be admitted that the design of the system is sufficiently important to warrant a close investigation of all the factors which bear upon its efficiency.

The great experience of Messrs. W. H. Allen, Sons and Co., Limited, in the construction of auxiliary machinery for naval ships, and the facilities for accurate testing and research which the firm have long enjoyed, have naturally resulted in the collection of a vast amount of data bearing upon the design of fans of all kinds, ranging from the engine-driven fans which formerly were the standard type, down to those geared to or direct-driven by steam turbines which represent modern practice. It is also not to be wondered at that the firm's interest in the efficiency of their fans should have led Mr. Richard Allen to investigate the efficiency of the various details which go to make up a complete forced-draught installation, because the effective capacity of a fan is dependent not only on the merits of the fan itself but upon the more or less advantageous manner in which it is installed. When the researches were first commenced, one of the first things to be discovered was the somewhat startling fact that the losses in the intake shafts amounted in some cases to over 50 per cent. of the total pressure developed by the fans, thus actually exceeding the useful pressure produced in the boiler room. As every inch of negative pressure at the eye of a fan reduces the delivery pressure by the same amount, the conditions mentioned not only showed an unconscionable loss of efficiency, but resulted in a very inadequate stokehold pressure through no fault of the fan. It soon became apparent that there was scope for great improvement in many directions and that the whole question of the supply of air to boiler rooms was worthy of much more attention than it had hitherto received. In the year 1916, Mr. Allen published the first edition of a work on the subject, which, however, could hardly be given the publicity it would otherwise have received on account of the war conditions prevailing at the time. It was nevertheless reprinted in 1918 and 1919, and now a second edition has been published containing the results of further developments, and bringing the matter up to date.

The present volume contains 15 chapters, each devoted to the consideration of some factor bearing upon the efficiency of a fan installation for stokehold duties on ships of war, although needless to say the conclusions in general have a far wider application. The sixteenth and last chapter gives a summary of the progressive improvements which have been made as the outcome of intelligent investigations into the sources of loss, and the results are most striking. As compared with conditions obtaining even so late as 1915, the performance of the fan installation on light cruisers had been improved by 1918 to a most remarkable extent, the intervening period having witnessed alterations of design made in accordance with the indications of theory and experiment. By the end of this short period, losses in total air pressure amounting to 3·05 in. w.g. had been eliminated, and the fans had been made to deliver an extra 70,000 cub. ft. of air per minute to the stokehold at an increased pressure of 0·6 in. w.g., simultaneously with a reduction in fan speed of 57 r.p.m., or about 8 per cent. This change for the better was in no way due to any alteration of the fan itself. Indeed both the engines and the fans remained the same throughout, their effective efficiency having been increased entirely by modifications of the intakes, air passages, &c., so as to reduce eddies and unnecessary resistances and to secure the nearest approximation to stream-line flow of the air.

We have already indicated the serious nature of the avoidable losses in the older installations, but actual figures are worth quoting. Standard 84-in. fans, which on test developed a pressure of 4·6 in. w.g. when running at 450 revolutions, and delivering their rated capacity of 40,000 cub. ft. of air per minute, would only maintain a stokehold pressure of 3·5 in. w.g. when running at 490 revolutions, although the pressure across the fans themselves under these conditions was 6·4 in. w.g. This loss of 2·9 in. w.g. was traced to intake losses at the cowls and in the shafts. Experiments were undertaken on various types of deck intakes, and although the design of these has of course to be subject to many practical considerations, such as those of size, freedom from injury and operation in bad weather, it was found possible to increase the coefficient of flow to 83 per cent. as compared with only 35 per cent. for the old type. The experiments were carried out on models with 15 different arrangements for the inlet of the air, and the lines of flow were rendered visible by means of silk ribbons.

Besides giving attention to the stream-line flow of air entering the intakes, and modifying the shape of the weather flaps to procure this, the same principles were applied to the design of armour gratings and splinter gratings. The bars in these being changed from a rectangular section to a section of stream-line form. The new type of armour grating bar was of the same depth as the old, but being considerably broader it afforded very much higher protection. Nevertheless, in spite of its greater width, it offered so little resistance to the air flow, that no pressure drop could be measured across a full-sized model arranged to represent working conditions, when air was passed down the intake shaft at a speed of 59·1 ft. per second. Under similar circumstances, but with an air velocity of only 53·7 ft. per second, a grating of the old pattern caused a pressure drop of 0·22 in. As, in an actual vessel, there are armour gratings at different deck levels, through all of which the incoming air has to pass in series, the aggregate saving due to the stream-line bars is evidently of material importance.

When fans are installed for working in parallel, it is evident that the airway through any idle fan must be shut off when the others are working. This was formerly provided for by means of inlet shutters, arranged to cover the eye of the fan when the latter was not in use. The eye was protected by a wire guard when the fan was working. Both shutters and guards have been replaced by a shutter on the Venetian blind principle with stream-line slats, which fulfils both purposes at once. The new type of shutter so improved the flow of air to the eye of the fan that the efficiency of a 90-in. fan, delivering its rated output of 60,000 cub. ft. of air per minute was increased from 53·6 per cent. to 59·5 per cent., the delivery pressure being raised from 5 in. to 5·5 in. w.g. Indeed the performance at all outputs was considerably better when the shutter was in use than when the inlet was entirely free.

As regards the fans themselves, the trend of development has been towards smaller diameters and higher speeds. Until 1909 the standard battleship fan was 81 in. diameter, but investigations showed it was possible to build a 52-in. fan which at 450 r.p.m. would give exactly the same output as the larger fan at 300 r.p.m. This permitted five fans to be placed in the space previously taken by four, or allowed four to replace three, as might be desired, with a consequent great increase in air delivery. The modern type approaches more nearly the lines of the Sirocco, having comparatively numerous and closely-spaced short blades. With the improvement of fans as regards size came a desire to ensure that the work of the impeller was utilised more efficiently. Attention was paid to the design of the casing, and the advantage of a correct volute over a concentric casing was established by actual tests. Among others, a 68-in. destroyer fan was tested over a considerable range, and it was found that at a discharge of 30,000 cub. ft. per minute, the volute casing increased the delivery pressure to 6·2 in. w.g., as compared with 4·71 w.g. obtained with a concentric casing, the speed in both cases being 500 r.p.m. Following this work, the provision of deflectors to direct the discharge of the fans in the required direction without shock, was studied, and this again resulted in substantial improvements in efficiency. The disposition of fans and their direction of rotation to obtain uniformity of air distribution between the furnaces was another important subject of investigation.

After a short chapter on the calorific value of oil fuels and the air required for their combustion, various calculations concerning air are exemplified, the treatment being of the simplest arithmetical nature. This is followed by a chapter on testing fans, the arrangements at the works of Messrs. W. H. Allen, Sons and Co., Limited, being described. These are, as might be expected, unusually complete, and have no doubt contributed largely to the reputation earned by the firm for this class of machinery.

In conclusion we should state that the book is admirably printed and well illustrated, while the author must be congratulated on having produced a work which cannot fail to be read with interest and advantage by all who are concerned with the handling of air in large volumes, on land as well as on shipboard.

BOOKS RECEIVED.

United States Geological Survey. Water Supply Paper No. 456. *Surface Water Supply of the United States,* 1917. Part VI. *Missouri River Basin.* NATHAN C. GROVER, Chief Hydraulic Engineer. Washington: Government Printing Office.

United States Bureau of Labour Statistics. Bulletin No. 273. *Proceedings of the Sixth Annual Meeting of the International Association of Industrial Accident Boards and Commissions, Toronto, Canada, September* 23–26, 1919. Washington; Government Printing Office.

Liverpool Shipping; Who's Who? 1921. Liverpool: *The Journal of Commerce.* [Price 2*s.*]

The Birmingham Exchange. Directory of Members, Subscribers and Representatives, 1921. Birmingham: The Birmingham Exchange. [Price 2*s.* 6*d.* net.]

The Evolution of Naval Armament. By FREDERICK L. ROBERTSON, Engineer-Commander, R.N. London: Constable and Co., Limited. Price 18*s.* net.]

Power House Design. By Sir JOHN F. C. SNELL, M.Inst.C.E., M.I.Mech.E., M.I.E.E. Second edition. London: Longmans, Green and Co. [Price 42*s.* net.]

Allied Shipping Control. An Experiment in International Administration. By J. A. SALTER, C.B. Oxford: The Clarendon Press. [Price 10*s.* 6*d.* net.]

The Engineering Index, 1920. New York: The American Society of Mechanical Engineers. [Price 6 dols.]

Lettering: A Handbook for Artists, Architects, Designers, Signwriters and Craftsmen. By ARTHUR E. PAYNE, A.R.C.A.Lond. London: B. T. Batsford. [Price 3*s.* 6*d.* net.]

Government of India. The Patent Office. Patent Office Journal, 1920. Calcutta: Superintendent Government Printing. [Price 1 rupee.]

Engineering Steels. An Exposition of the Properties of Steel for Engineers and Users to Secure Economy in Working and Efficiency of Results. By LESLIE AITCHISON, D.Met., B.Sc., M.I.A.E. London: Macdonald and Evans. [Price 25*s.* net.]

Electrical Machinery. A Practical Study Course on Installation, Operation and Maintenance. By F. A. ANNETT. First edition. New York and London: McGraw-Hill Book Company, Inc. [Price 18*s.* net.]

LOW-TEMPERATURE CARBONISATION OF COAL: ERRATUM.—In the discussion at the recent meeting of the Institution of Mechanical Engineers, following Professor Bone's paper on "Low Temperature Carbonisation," on page 68 of our issue of the 9th inst., Mr. R. J. Sarjant is reported as saying in regard to the plant at Barugh, that "the coke produced was dumped . . . and burnt under waste heat boilers." His statement was that the coke was dumped from the ovens into waste heat boilers where its sensible heat was utilised in raising steam for the by-product plant.

THE TURBINE DRIVEN QUADRUPLE-SCREW

CONSTRUCTED BY THE SOCIÉTÉ ANONYME DES CHA

(For Description, see

Fig. 1.

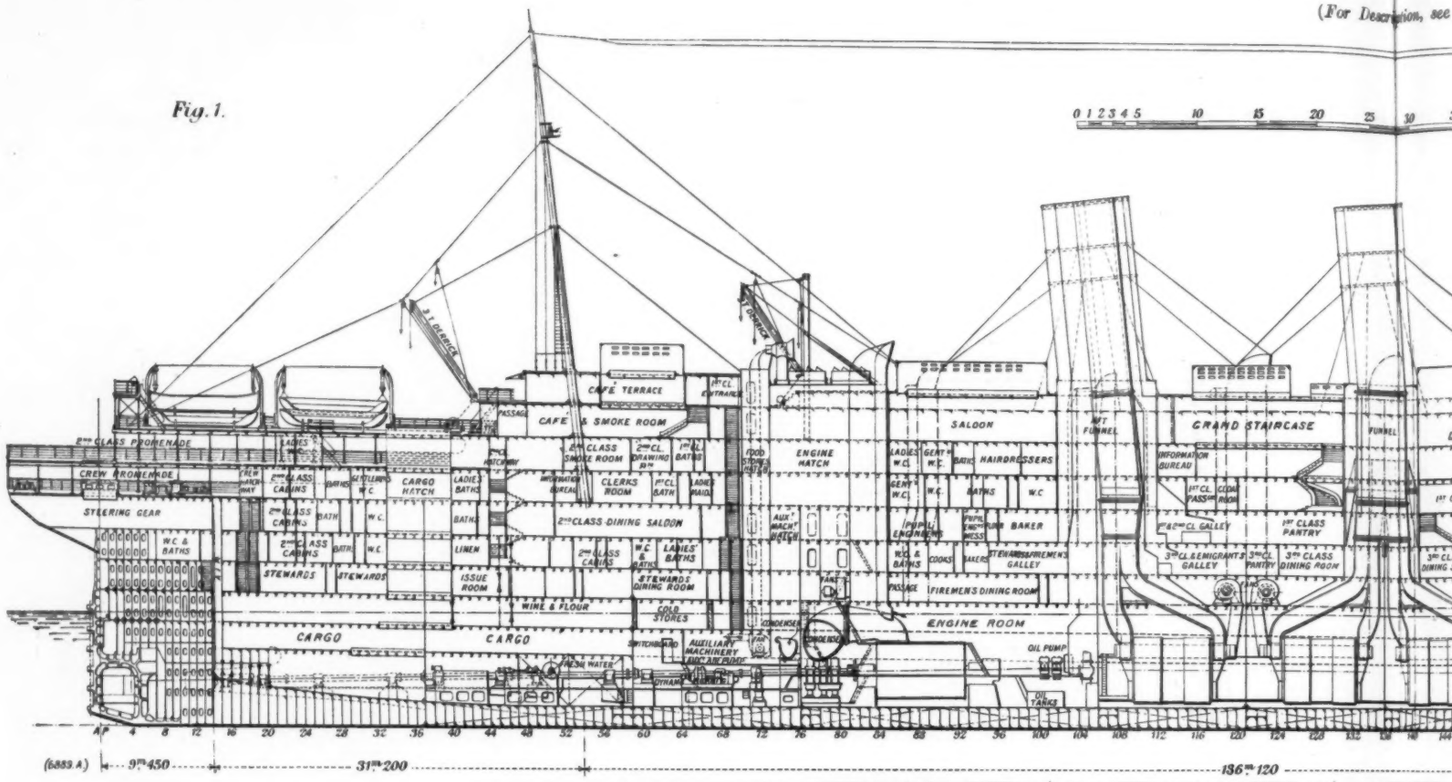


Fig. 2. DECK A

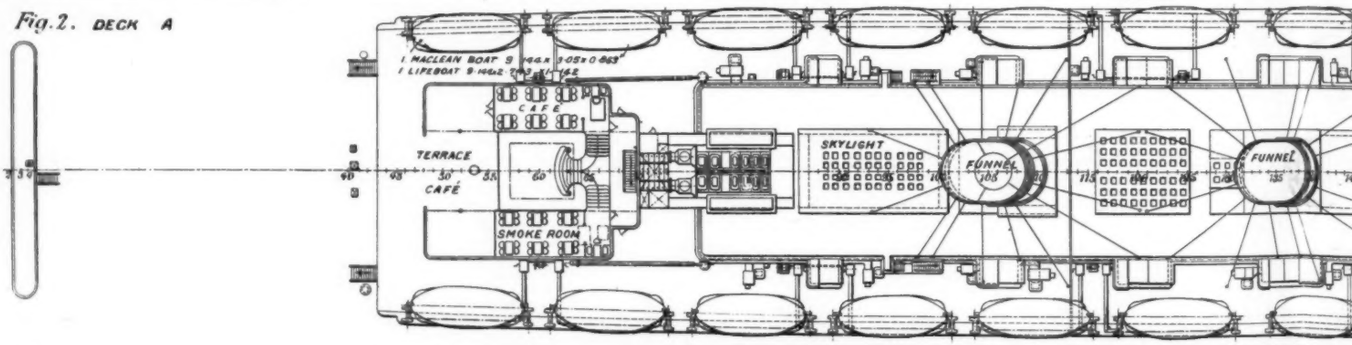


Fig. 4. DECK B.

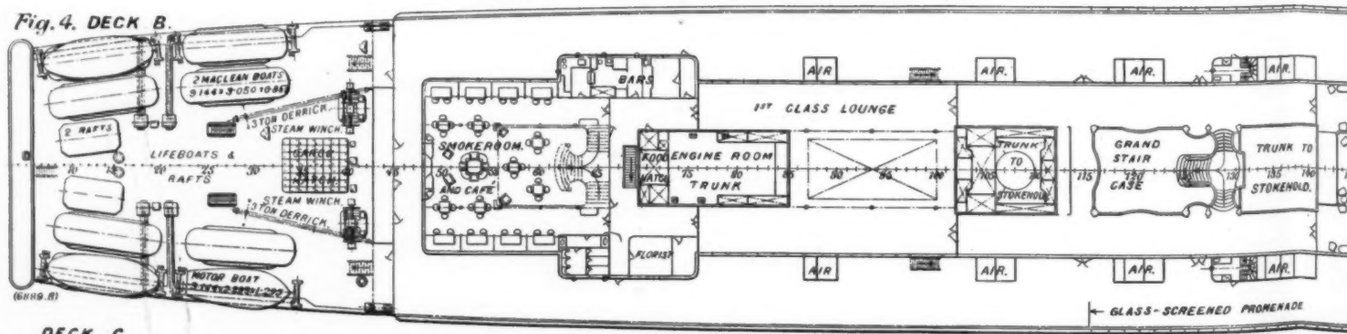
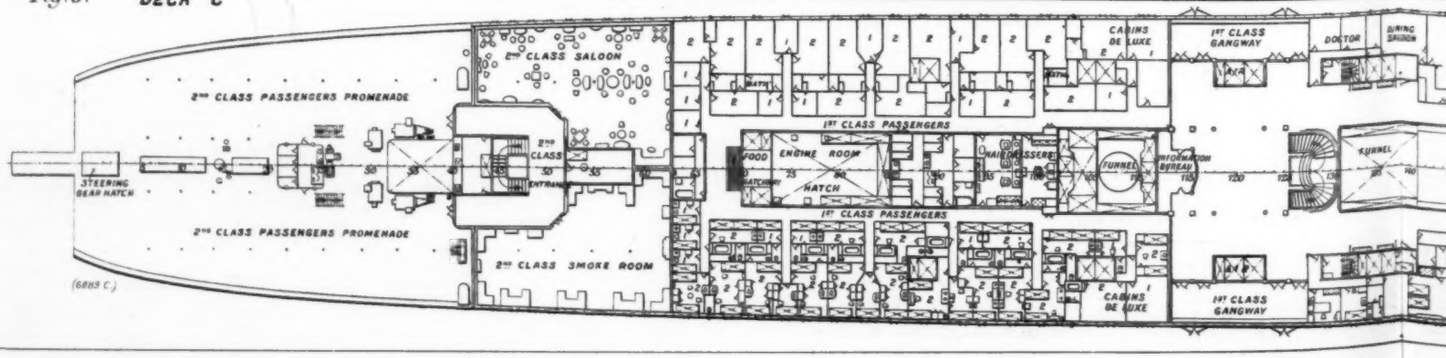


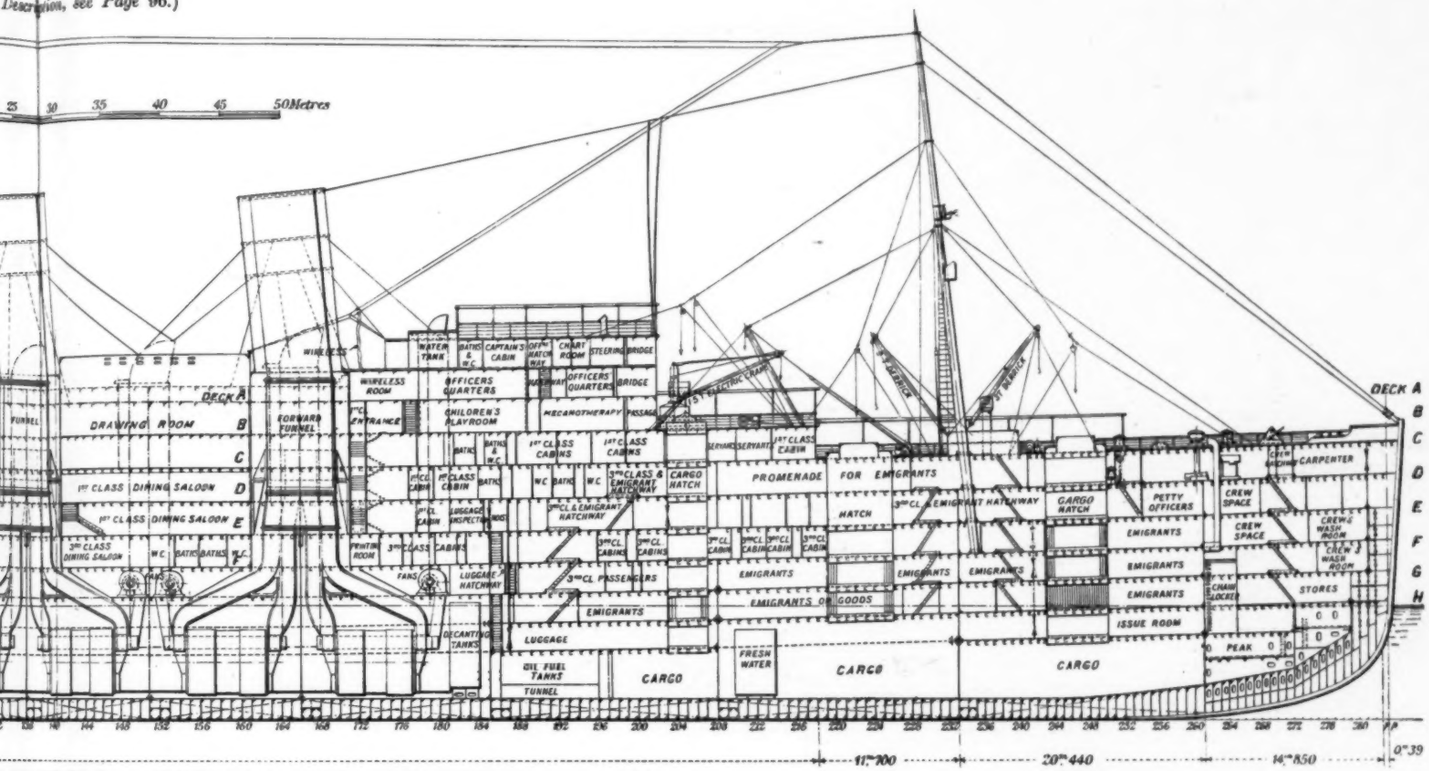
Fig. 5. DECK C



-SCREW TRANSATLANTIC LINER "PARIS."

IE DES CHANTIER ET ATELIERS DE ST. NAZAIRE.

Description, see Page 96.)



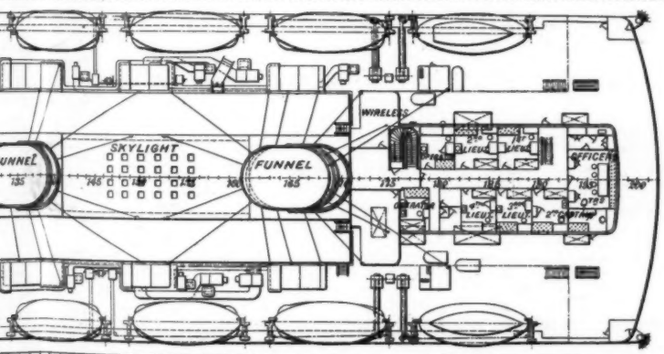
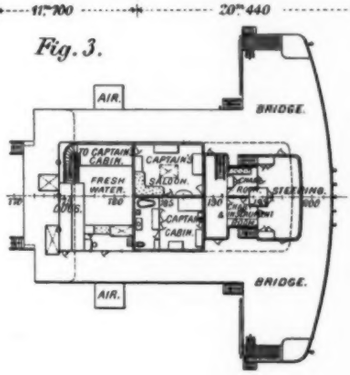
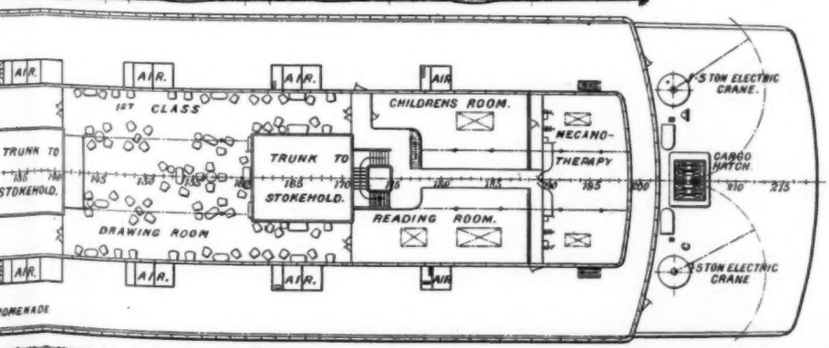
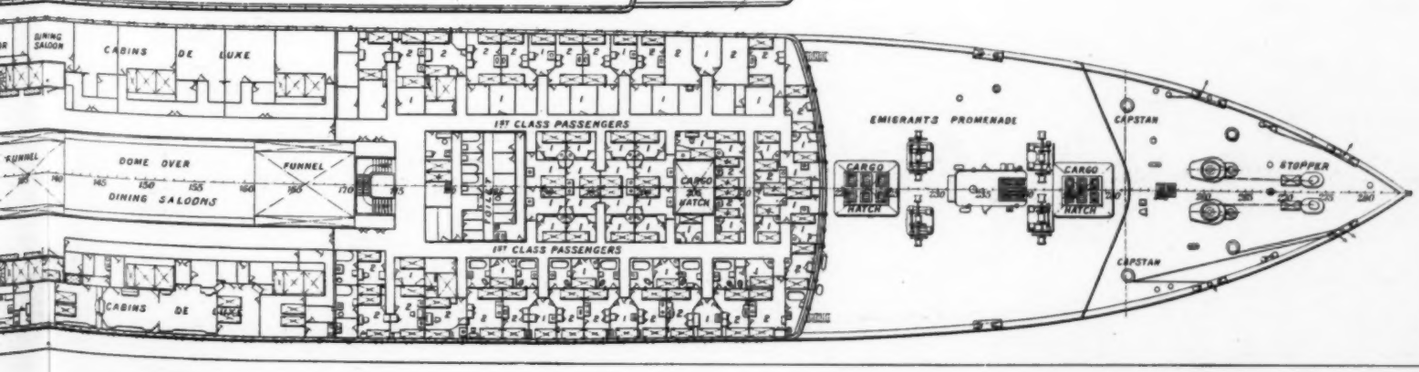


Fig. 3.







INSTITUTION OF CIVIL ENGINEERS, ENGINEERING CONFERENCE.

(*Continued from page 56.*)

SECTION IV.—MINING AND METALLURGICAL PROCESSES.

THE EXISTING PRACTICE OF INSPECTING WORK AND MATERIALS.

THE last paper read at the meeting of this section on Thursday, the 30th ult., was on the above subject, the author being Mr. G. Hatton. We reproduced it on page 84 of our issue last week.

Mr. Stanger said he was one of those who tried to earn a living by doing the very thing Mr. Hatton wished to have put into one organisation. In the last paragraph of Mr. Hatton's paper they might read that in the United States of America the work of inspection had been largely systematised under one general organisation. He had made some enquiry but had not been able to find that the one organisation was very largely used nationally. In fact he had been asked by a certain city engineer to state that that engineer had been inspecting a lot of material over in America, but had not made use of the one organisation because, he said, it was not in the district where he wanted it.

Sir Westcott S. Abel said that Mr. Hatton had referred to the work done by Lloyd's Register of Shipping. Broadly speaking, all that Mr. Hatton asked for was actually being carried out by Lloyd's Register of Shipping for the shipbuilding industry. He thought Mr. Hatton was largely concerned with the question of tests for reception. In the United Kingdom alone Lloyd's Register had, he believed, about 26 steel testors resident in different districts and seven casting and forging inspectors. In addition there were inspectors all over the world—several in Germany and one as far as Corea—all engaged in testing material to the British Standard Specifications. Lloyd's Register of Shipping had done special work to an enormous extent during the war; the Ministry of Shipping had asked them to carry out special specifications, which they had done, he thought, very conveniently; but as a rule they did not do that unless a special request was made. As an instance of the magnitude of their work, they carried out roughly tests on 2,000,000 to 2,500,000 tons of steel per year. They tested about 90 per cent. of the steel used for shipbuilding purposes in the United Kingdom. As an example of the special nature of their work, during the war, they had, on behalf of the French Government, looked after about 1,500,000 tons of steel of a special quality for shells. All this work was done under the control of a committee of the industry comprising engineers, shipbuilders and steel makers. All the work was done by a central bureau in that general sense. Sometimes it was an advantage to steelmakers or others to test materials to a particular specification, and Lloyd's Register were occasionally asked to do this. If the specification was one that was usually deemed to be good practice, or was a standard specification, they had no hesitation. But there were occasions—and such occasions might arise with the central bureau if it were established—where they were asked to test materials to an agreed on specification between purchaser and manufacturer, where experience told them they would be giving a hall-mark to bad material. In such cases they generally refused to carry out the work. One other point was that Lloyd's Register had to give a certificate that a vessel was of good character; and they were obliged to do this on the personal observation of their employees. He was afraid although they might extend their activities somewhat to help the general body of engineers, it would not be possible for Lloyd's altogether to make use of another organisation; because they had to depend on the personal report of individuals.

Mr. K. N. Mannaberg said that he spoke as a steel maker and personally was very grateful to Mr. Hatton for bringing this subject forward. Steel makers did not know how to bring it before engineers. He did not think the general engineers realised to-day how the testing was done, and how it wasted time, money and energy. But the steel maker, or steel works manager, had eight or ten inspectors at his works every day. There was waste of time, overlapping, and the testing was done inefficiently. It was inefficient because the people who came to the steel works were not very capable. He supposed they were not paid sufficiently to be otherwise. They were often people who had never seen a steel works, and did not know anything about steel; and were engaged in testing steel which had already been tested by other people far more efficient than themselves, for instance, Lloyds; and rejecting it because they did not know that it was first-class steel for their purposes. It was a usual practice to send the inspector when the order was completely rolled. It would not pay to send the inspector down large distances for every partly rolled order. Very often it occurred that eight or ten sections were required for that order—channels, angles and so forth—and the inspector did not come until the last section was rolled. The whole parcel had to wait sometimes for months before it could be dispatched. That was undoubtedly against economy. The cost to the works was enormous. After all, the user as a rule had to pay for the cost of an article; and if the cost could be decreased it was as much to the benefit of the user as to that of the maker.

Mr. C. P. Sandberg said there was so much thorough good commonsense in the author's suggestions and Mr. Mannaberg's remarks, that he did not doubt engineers generally would approve the views expressed and whenever possible try to form a special body. That was a matter on which he thought there might be considerable difficulty. In America, where one organisation had been referred to, they suffered, he believed, to a certain extent from a multiplicity of inspection like the British manufacturer. As to engineers selecting really competent men who knew their job, that was a matter which they ought to understand was of very great importance to themselves, and much more satisfactory to the makers. He ventured to think that this evil was disappearing by degrees, and that a better type of men were being appointed. It was responsible work to have to carry out, and it was to be hoped that the right men would be selected.

Professor Dalby said there was one aspect of this case which might interest the present gathering. A well-known representative of Lloyds had told him that one of the difficulties of testing at steel works, and generally, was the variety of designs which engineers produced for the same purpose and for the same article. One specification ought to serve the lot, but one found each specification slightly different according to the engineer. This multiplied inspection and made it difficult. To get over the difficulty there had been working during the last two or three years a committee of manufacturers and others—Lloyds and the Board of Trade were two of the parties represented—which had agreed on common specifications for tubes and plates, and on the general dimensions of marine boilers. He believed they were going on to consider engines. He thought that was one direction in which a great saving of expenditure would be found—the standardisation of design through a body like this backed by the inspection of the Standards Committee. He thought it would be difficult to appoint one central authority which would be generally accepted by all England for definite purposes. The North-Western Railway bought a great many tons of steel a year for their subsidiary lines, and would find it difficult not to test it themselves, and to their own specification; but things were tending towards greater unification of tests and towards greater unification of designs. He believed we should find a solution of a great many difficulties in that direction.

Mr. W. H. Shortt felt that in many cases the authors of the specifications were the right people to inspect the material; but he had often regretted that it was not possible to get the British Standards Committee to make inspections in certain cases. On the other hand the specifications of this Committee were general, and he had found in many cases where he wanted to work to the specifications, that he had to issue a subsidiary leaflet describing the modifications that were wanted. The permanent way engineer who was the user, and was responsible for the behaviour of rails when in the track, was the man to be responsible for inspection.

Mr. H. B. Spencer, speaking from the point of view of the inspecting engineer, said he had spent a fair number of years in inspection work, particularly about twenty years ago, and had often felt somewhat apologetic in going to steel works, simply because he felt the duplication must be a serious difficulty, and he had been astonished at the courtesy he had always received under those difficult conditions. He would hope that, as the result of this paper possibly, civil engineers might give a start by appointing a committee, or having the matter carefully considered to see in what way these difficulties could be removed. Of course, besides material there was the question of finished work, which it seemed to him came under an entirely different category; so he thought the question needed to be considered in a very much wider fashion than could be done at that meeting. There was an association now dealing with the question, the Technical Inspection Association; it was quite in its infancy, but it had already done useful work. On the Council of that Association there was the head of the Inspection Department at Woolwich, the head of the inspection of the Air Force, a member of the Inspection Department of the Board of Trade, and there were besides a member of a very eminent firm of inspecting engineers and two or three others actively engaged in inspecting. These were considering at the present time such questions as the remuneration of inspectors and the raising of the status of inspectors, and he was sure that this Association, with which he was connected, would be very glad to give any assistance, if this matter was going to be fully discussed with a view to bringing about a better state of things.

Mr. Hatton said there was not very much for him to reply to; he would like to say that he was quite satisfied with the result of the discussion and the spirit with which his suggestion had been met. With regard to Mr. Stanger's criticism of the last clause in the paper about the practice in America, he (Mr. Hatton) must plead guilty to having referred in that way to the practice in America very largely on hearsay. He had had a little American work done, but the view he had expressed was perhaps more an impression than anything. He could not prove the statement and would accept Mr. Stanger's qualification of it. Sir Westcott Abel did not find fault with the general principle of the paper, though, naturally, he looked upon it from the point of view of Lloyd's Register. All that he (Mr. Hatton) asked was for some such co-ordination as he had suggested, but his mind had not gone so far as to formulate any idea as to the exact details of how the matter should be carried out. All he wanted to do was to call the attention of engineers generally to a condition of affairs which required a remedy in some way. Mr. Spencer had made some very interesting remarks; it was interesting to hear that the subject had not been overlooked, and that engineers were considering not only the status of the inspectors, but, generally, the consolidation or simplification of the specifications and systems of inspection. It was all in the right direction, and he thought those present would agree with him that his note had not been absolutely devoid of result. He was gratified at the way in which it had been received.

SECTION V.—SHIPBUILDING.

The first paper to be dealt with at the meeting of Section V on Thursday morning, the 30th ult. was that by Mr. W. L. Roxburgh on the "Necessity for and the Possibility of Development of the Coasting Trade," which had been left over from the programme of the previous day. This paper we reprinted on page 32 *ante*.

DEVELOPMENT OF THE COASTING TRADE.

The chairman, Engineer-Vice-Admiral Sir Henry J. Oram, K.C.B., called upon Mr. Roxburgh to read his paper, and the first speaker in the discussion which followed was Sir Alfred Read, who remarked that greater opportunities existed in the British Isles for the coasting trade than in any other country. It was, however, essential that facilities for the quick and cheap handling of the goods at the ports should be provided and that

vessels should be able to get to their berths immediately on arrival. Most British ports were subject to tidal conditions, and vessels were held up by the tide and had to anchor for many hours before they could be berthed. Present-day financial conditions made it difficult for harbour authorities to give facilities for the coasting trade, but he hoped that, before long, they would be able to do so, because it was through the coasting trade that the overseas trade was maintained and developed. The engineer and shipbuilder had co-operated in the production of efficient ships, and some of the finest were to be found in the coasting trade of the United Kingdom and the short sea trade. They were provided with up-to-date machinery and were run economically; but that was useless unless they, and their cargoes, could be quickly and economically handled in the ports.

Asked whether he could give an example of a smaller port of national importance which was not sufficiently developed, the speaker said there were many ports in the United Kingdom which were worth developing, but it was not for him to say whether such development was absolutely necessary. There was Poole, for instance, where there was a very bad shifting bar and vessels drawing 14½ ft. of water could very rarely get into that harbour. Portsmouth, again, was subject to Admiralty conditions, and merchant vessels were there on sufferance. He had many times impressed upon the Mersey Docks and Harbour Board the necessity for providing the port with a half-tide dock, whereby coasters and similar vessels could dock at any state of the tide. Ships up to 3,000 tons d.w. might come up the Channel and just lose the tide, and have to anchor for 8 to 10 hours, which would be avoided by a half-tide dock.

Captain H. B. Hooper, the next speaker, endorsed what had been said with regard to the difficulties experienced by the coasting trade at the hands of the railways, but added that there were further difficulties in connection with the 8-hour day. Most of the coasting trade was done on tide work. Vessels entered and left the ports on the tide, but, as the men adhered to the 8-hour day, a vessel arriving in port in the afternoon was practically hung up until 8 o'clock the next morning. The coasting trade was subject to that oppressive limitation.

With regard to the development of the coasting trade, the speaker thought that the necessary organisation was already in existence in the form of shipowners, ports and ships; but cheap railway rates and heavy expenses prevented coasters from competing for the carriage of goods to anything like the fullest extent. Increased facilities, he thought, should be offered by the ports to the short sea trade, and he ventured to suggest that many people were obsessed by the advantages of the big ship. In this connection he mentioned that a certain vessel carrying 8,000 tons to the Port of London made four voyages a year, whereas one of the speaker's ships, carrying 1,000 tons, made 48 voyages a year.

The small ship the speaker was referring to had suffered from having to wait to get over the tunnel under the Thames, and it was sometimes nearly high water before she was able to get into her berth or the London docks, because of the mud in the river. London in that respect, he said, compared rather badly with Rotterdam, because, at the latter port, small ships were able to get alongside their berths at all states of the tide; the facilities for loading and discharging at Rotterdam were also much superior to those in the Port of London. The speaker also referred to difficulties in connection with overtime work, and added that although improved facilities at the ports were necessary, he did not approve of Government subsidies. He thought, however, that, where the trade showed that it could be developed, the Government might advance money at a moderate rate of interest for the purpose.

Mr. S. Donaldson, who followed, said he would like to ask whether Mr. Roxburgh had spoken of railway competition from his own personal experience. To-day the tramp coasting rates were fairly good, but a lot of the traffic which was carried by coasters before the war now went by rail. The cause of that was not the scarcity of tonnage during the war, but the fact that the Government commandeered about 85 per cent. of the coasting vessels. The speaker's vessels, he said, had carried slates from North Wales at a very moderate rate before the war. During the war those slates were carried by rail, but after last year's increase in railway rates, that traffic had returned to the coasters and was carried much cheaper than by rail. Another result of the rise in railway rates was that flints were carried from Kent to the Potteries by coaster. At the present time, he said, coasting rates were fairly good, and, except in odd instances, the railway companies were not cutting into the coasting trade, as far as he could see. With regard to the suggested expenditure on port improvements, the speaker pointed out that the great bulk of the coasting trade was carried in steamers up to about 1,000 tons dead weight, and, on the whole, he said, the ports were fairly well equipped to deal with such vessels. Whatever was done in that respect, he was very much against asking the Government to advance money to any of the ports for the purpose of fitting them to accommodate larger tonnage, because very large tonnage was not wanted on the coast. He thought the matter might safely be left to the working of the law of supply and demand.

Mr. R. M. Parkinson, who spoke next, said that the question of rates had an important bearing on the subject before the meeting, and quoted a number of rates for water-borne traffic which were considerably below railway rates. The real drawback to coasting traffic, he said, was the time and trouble it involved. He then quoted some instances of the difficulties experienced by shippers. Some means of bringing the ordinary trade into touch with the carrying companies, he said, were needed, as, unlike the railway companies, the carriers scarcely seemed to bother themselves about the trader, who had to find out about shipping for himself. The same was true of barge traffic.

The next speaker, Mr. R. Williamson, said that the paper evidently referred only to the English coasting trade, because one could not get to France or to Ireland by rail. The author laid it down that the problem of transport was of the greatest importance to the whole nation, and should be settled by statesmen, but if that meant Government interference, he was totally opposed to it. During the war the speaker's own boats, on Admiralty charter, did not do half the work they ought to have done, and, to his mind, that showed how detrimental Government control was to the trade of the country. There was no doubt that in every business there were inequalities in rates, and railway companies, in this respect, were like other private traders. As soon as they were decontrolled, however, a different state of things would come about. He had the strongest objection, which, no doubt, was shared by Mr. Roxburgh, to the fixing of rates. If rates were fixed by the Government for the railway companies, there was no reason why they should not be fixed for the coasting trade. Better equipment and facilities at the smaller ports would be beneficial to the coasting trade, but if the Government provided the capital, they would make regulations which would interfere with profits. The difficulty at many of the small ports was that the coasting trade was suffering from a shortage of traffic, and that could only result in low freights. One thing that required more attention was the details of the ships, to which very little attention was paid in the coasting trade, but more especially the tramp trade. The majority of the coasting steamers were under-boilered, and the owners were trying to drive them at an uneconomical speed, with a consequent large increase in fuel consumption. With reference to the statistics in the Paper, showing a loss of traffic between 1914 and 1919, which was assigned to the uneconomical railway rates in vogue, the speaker pointed out that during the war the Government requisitioned something like 90 per cent. of the coastal tonnage; consequently there was no tonnage to carry cargo, and every possible cargo was transferred to the railways. Cargo-owners had to face very high insurance premiums for war risks, as well as great delays in transit, and that, to a very large extent, was the reason for the falling off in coasting traffic.

The last speaker in the discussion, Mr. A. P. Matthews, said that there were two distinct sections of the coasting trade, the tramp section and the liner section. So far only the tramp section had been dealt with, but it was the liner section which had really fought the railway companies for the last two years. He was referring to the liner companies who dealt with purely general cargo, and were in competition with the railway companies and giving an equivalent service. That business was regarded by the Government as essential to the life of the nation, because, in the event of a railway stoppage, it was the only means of carrying on the traffic. On the question of rates, he had been glad to hear that some of the speakers were satisfied and had no fear of railway competition, but he pointed out that the railway companies did not compete so strongly with the tramp as with the cargo liner. There were no establishment charges in connection with tramp steamers, whereas these were very heavy in the case of the cargo liner. Therefore, when a railway company was able—as had happened lately—to cut the rates on port-to-port traffic, and make it up on the inland traffic, the liner companies felt the competition very much. The accommodation provided at ports for the coastal trade, the speaker continued, had been mentioned by Sir Alfred Read. All port and dock authorities gave preference to the ocean trade, and that was one of the difficulties those in the coasting trade had to contend with. With regard to the turning round at ports, it was a physical impossibility for the railways to take all the traffic which came in ocean steamers. If the coasters were eliminated, all ocean liners would be delayed at the ports, as had happened during the war.

Mr. W. Roxburgh, who was then invited by the chairman to reply, said the discussion had been very full and much information had been given by speakers on both sides. In answer to Mr. Donaldson, he would say that the rates mentioned in the paper were the results of his own personal experience. He shared Mr. Williamson's objection to Government control of rates, either on the railways or at sea.

Fabricated Ships.

After thanking Mr. Roxburgh for his paper, the chairman called upon Mr. M. E. Denny, C.B.E., to read his paper on the Design of Fabricated Ships from the Labour-Saving Point of View, and afterwards on Mr. J. C. Telford, O.B.E., to give his paper on the Economy of Labour on Shipbuilding as Effected by Fabricated Ships, &c. The two papers, which we reprinted on page 84 of last week's issue, were discussed together.

In opening the discussion, Sir Westcott S. Abell, K.B.E., congratulated the authors upon raising so many interesting points in regard to mass production and manufacturing problems generally. A good deal had been done in the way of mass production during the war, and it would be a pity not to put some details of it into practice in the shipbuilding industry of to-day. The design of details was important to successful mass production. As an illustration of what could be done in that way, he showed a model of a double-bottom in which all the component parts could be fabricated. With regard to the large number of trades concerned with shipbuilding, as Mr. Denny had suggested, the fewer those trades became the lower the cost of building a ship would be. There would be greater speed in building and less friction among the workmen, since there would be fewer unions to interfere with each other. During the war the number of patterns of rolled sections had been greatly reduced, the designs for the convoy sloops containing only 8 or 9; by this means the cost was much reduced. The speaker had never agreed with the adoption of straight frames and beams. It was, he said, more difficult to straighten a bar than to bend it and, particularly in the case of decks, he would rather bend a bar to a regular camber than attempt to straighten it. Moreover, the absence of camber entailed a penalty in the shape of dead weight. With reference to the question of scrap raised by Mr. Telford, one had to allow for something like 200 tons or 250 tons of scrap with an 8,000 tons dead-weight vessel. That scrap had to be transported from the steel works to the shipyard, collected again

in the shipyard and sent back to the steel works. It therefore followed that the greater the amount of work that could be done at the steel works the better. A good deal of rough shaping, punching, and multiple punch work could be done at the steel works with advantage, and without handicapping the ordinary shipbuilder in any way. Bevelling, the speaker continued, was particularly referred to in one of the Papers. In that case the angle sections were rolled with three standard bevels of 90 degrees, 100 degrees, and 110 degrees, and practically every frame in the ship was bevelled to those standards through an ordinary bevelling machine. He suggested that the frames might be bevelled entirely at the steel works to a gauge supplied by the shipbuilder.

Association with bridge makers had taught shipbuilders many things, one of which was the advantage of multiple drills. The punch and the multiple punch did the work in the shipyard, but multiple drills were certainly very much more flexible than multiple punches; any sort of hole could be drilled, and he believed the work was done with economy in ordinary conditions. The comparative cost of drilling and punching was being worked out at several shipyards, notably at Messrs. Yarrow's, and, so far, the figures, though incomplete, favoured the former process. There seemed, however, to be one drawback to the work done in the bridge yard—it cost considerably more to prepare the material than in the ordinary shipyard. The reason for this, he thought, was that bridge builders took exceptional care and got too great a degree of accuracy in their ordinary work. It was not easy to imagine any riveted structure being exposed to a greater strain than a ship at sea; yet the accuracy adopted by bridge builders was very much higher than was found to be necessary in shipbuilding practice. Mr. Denny had given a good deal of consideration to the adoption of multiple punching machines, which made for great economy in labour and enabled plate material to be prepared at twice the ordinary speed. Unfortunately, the multiple punch worked so quickly and efficiently that it was out of step with the rest of the work in the shipyard and was often idle for half or three-quarters of its time. In conclusion, the speaker referred to the advantage of getting plates of uniform length and breadth, as was done in connection with the fabricated vessels, and mentioned that if they were made in multiples of the rivet spacing it would conduce to greater efficiency and economy.

Mr. W. H. Whiting, C.B., the next speaker, said that it was not altogether clear that the two authors were recommending the same thing, or meant quite the same thing by "fabricated ships." Mr. Denny's definition—"the assemblage, to form a ship, of parts previously worked up in an establishment other than the shipyard"—was careful and exact; but nothing was said about the nature of the establishment. Again, it was proposed to interpolate between the rolling mill and the shipbuilder a new agent, whose duty it would be to punch, drill and work the material generally. Obviously the erection and riveting of the ship was reserved for skilled labour in the shipyard. That, the speaker said, was not an academic question, because in the big works at Chepstow there was a machine shop about a mile away from some of the yards and on the opposite side of the river. He enquired whether it was proposed to punch, drill, shear and roll the plates in such a shop, or whether it was intended to do the work at the rolling mills. Despite his experience of bridge builders' yards, Mr. Telford recommended the adoption of bridge builders' methods in shipyards, and not the actual carrying out of the work in bridge builders' yards, as a means of cheapening the production of ships in the future. All Mr. Denny's suggestions, the speaker pointed out, might be applied to ordinary ships as well as to fabricated vessels. For instance, the use of straight deck beams, the abolition of sheer, the omission of the stem, and so on, would lower the cost of any ship from the point of view of labour saving. He would like, however, a clear definition of the distribution of the work between skilled and unskilled labour, and to know how far the author's experience during the war confirmed the distribution mentioned in the papers. He also asked what were the reasons for the complete failure, as he understood it to be, of the attempt to build fabricated ships at Chepstow.

Mr. J. Reney Smith, who continued the discussion, remarked that it was important to remember that, in the early stages, the production of fabricated ships was a war emergency measure. The demands on every shipyard were suddenly and greatly increased, and the shipbuilder had to call on allied trades to help him. It was very desirable that the experience arising from the great effort that was made should be on permanent record, but, generally speaking, there would be little tendency to reproduce those emergency ships. On the other hand, the cost of producing the older types, and of completing each ship as a separate entity, had risen enormously, but he thought that, left to themselves, the shipowner and shipbuilder would produce a vessel which everyone would recognise as a British ship, cheapened in cost, it may be, by the introduction of some of the usable features of what, in itself, was merely a floating tank. Economy in ship production, the speaker thought, lay in the direction of multiple manipulation in the yards and of more machinery, but the prime necessity was to induce the workman to give his pre-war output and to take his old interest in building ships. The present cost of ships was absurd, a moderate-sized vessel now costing about four times the 1911-12 price. Some reduction was most necessary in the interests of the British shipbuilder in meeting foreign competition, and the reduction could only be achieved by the aid of improved methods and machinery, and by the re-animation of the workmen with the spirit of the past. If that were accomplished there need be no fear of competition.

The next speaker, Mr. J. H. Narbeth, C.B.E., said he had been concerned in the preparation of the designs of warships which were built very quickly and cheaply, and the principles laid down by Mr. Denny indicated the proper method of procedure for practically all ships. The speaker criticised the appearance of some of the American fabricated ships, in which, he said, there was no sheer, the derrick posts and funnels were vertical, and the ends of the ship were both alike. A seagoing vessel, he thought, should have a good sheer and, while everything of value in the fabricated ship was retained, designers should try to produce good-looking ships. He was strongly in favour of a curved beam, and said it was quite as easy for shipyard men to give a beam any particular curvature as to make it straight. There was, moreover, a serious practical objection to the straight beam, in that the plating of the ship could not be made sufficiently thick to prevent pocketing, or drooping, between the beams. He was rather surprised at the extent to which the plates of the fabricated ships had been drilled instead of multiple punched. He also thought that Sir Westcott Abell's suggestion of bevelling individual frames at the steelworks was not sound, as the frames would be damaged in transit, and it was also doubtful whether the steel works would do the bevelling very well when the rate of handling was remembered.

Continuing his remarks, the speaker said he was greatly surprised that the building of the straight-line ships had not led to a more general adoption of cheaper methods of shipbuilding. The straight line ship, with fabrication which would preferably be done in the yard that built the ship, offered a very wide field for the simplification of ship construction. By using the word "interpolate" in his paper, Mr. Denny rather gave the impression that he did not quite like the idea of fabrication. In the speaker's opinion, the best place for doing all the multiple work was the shipyard, close to the vessel, and if pains were taken to learn from fabrication practice whatever was valuable and to adopt it as a matter of ordinary shipyard work, it would help in the production of cheaper ships. Fabrication, the speaker pointed out, was not adopted altogether as a method of producing ships with great rapidity, but in order to utilise unskilled labour on a large scale. Before the ships could be put together preparations had to be made, which were not completed in time to show the value of the method. American experience undoubtedly showed that fabrication was an excellent plan in the production of ships in large numbers and in a very short time. A proper system of delivery of the fabricated parts to the shipyard, in correct numbers and descriptions, was, however, absolutely essential to success, and he was surprised that Mr. Denny had not emphasised that fact.

Mr. J. Foster King, C.B.E., said that, during the past year, he had had an opportunity not only of dealing to a large extent with the structural design of the so-called N standard, but of seeing in Japan and in America what could be done by fabrication, and what should not be done. Broadly speaking, he thought that British shipbuilders had been, as usual, a little too content to accept their own methods as the epitome of all experience, and a little too slow in adopting what might be done in the way of saving time, labour and materials both in the machinery and the methods for building ships. The Coghlan Works, Vancouver, were a splendid example of what might be done with superior organisation. During the war, with very simple but very complete erecting and fabricating arrangements, that works built 8,000-ton dead weight steamers in almost as many weeks as it took months in this country. That was done by fixing and retaining dimensions and using templates and multiple punches. He had also discovered, both in America and in Japan, that where fabrication was pursued beyond its natural position—namely, amidships—it paid neither in time nor cost. The British designer, he thought, should therefore concentrate on adjusting his designs in the direction of simplicity, of template work, of using one size of plate as much as possible, and of the multiple punch. Combining with those things their own past experience, and their recollection of the cost and difficulty of over-elaboration, they could accelerate and cheapen shipbuilding in this country by possibly 25 per cent. in the case of the ordinary freight steamer.

Sir Archibald Denny, Bart., the last speaker in the discussion, said that when a certain bridge builder started building ships he built them as he had formerly built bridges—everything was templated. As many loftsmen were employed on templating as he, the speaker, had carpenters and iron workers engaged in the yard; in addition there were the men who were doing the erecting. The speaker pointed out that, in his yard, they worked the reverse way, eliminating people from the initial stages of the work by gradually introducing templates. This led to simplicity in working and was a distinct advantage over the other method.

Mr. M. E. Denny, who was then called upon by the chairman to reply, said that Mr. Whiting had virtually enquired whether he, the speaker, meant to put the fabricating establishment in the steelworks, or whether the shipyard should be the present one replete with appliances and skilled labour or simply an erecting shop with 80 per cent. of unskilled men. That difficulty, he said, had occurred to him when he began to consider his paper, and he had been unable to see a way out. He was not prepared to write a paper on a shipyard being simply an erecting shop, with no machines, and employing a large percentage of unskilled labour. Neither was he prepared to say that the shipyard should be a high-class establishment fully equipped with the most modern machinery and manned by highly skilled mechanics. He had, therefore, to keep in view an establishment after the nature of Chepstow, which had some machines and was intended to have a backbone of skilled labour. The absence of skilled labour, due simply to the shortage of men during the war, was, he thought, the cause of the failure which, given sufficient time and more favourable conditions, would have been avoided.

Mr. Whiting here enquired whether Mr. Denny had thought of putting the large manufacturing or fitting shop as far away from the actual shipbuilding works as at Chepstow; and whether that was a contributory cause of the failure. To this Mr. Denny replied that his own opinion was that the fabrication of ships, as understood during the last half-dozen years, would not persist in this country, owing largely to the fact that individuality was a strong British characteristic. He agreed

with Mr. Narbeth that it would be better to adopt in ordinary shipyard practice whatever was good in fabrication, and that the ordinary shipyard should become its own fabricating shop. That was the speaker's own conception of fabrication in Great Britain in the future. Mr. Whiting had suggested that fabrication might be extended to every shipyard, which was correct. The point was that the present attitude of labour rendered the production of new designs difficult. The designer could produce a ship without a curved frame, but to get labour to see that they might produce it more cheaply to the shipbuilder and, therefore, to the shipowner, was quite a different thing. He also questioned whether the cost of the straight framing would be less than if it had been curved.

Mr. Narbeth, the speaker continued, had commented on the absence from the paper of stress on the system of delivery of parts in the proper rotation to the shipyard. It was quite obvious that the success of the work depended on the proper delivery of the material. That, however, was more in the province of the manager. As to the suggestion that a fabricated ship could be made as light as an ordinary vessel, it had been done during the war, but the Admiralty and the classification societies had got together, and the rules of those societies had been somewhat relaxed. For that reason five or six sections were used, and the ultimate ship was, perhaps, not heavier than her prototype of the more usual form. It was questionable, however, whether the classification societies would now permit the use of three or four sections to produce a ship as light as could be done by using a greater number of sections.

Mr. Telford, who then replied, said that a reduction in the number of sections was very desirable and was helpful in connection with fabrication. With regard to the amount of scrap which had been referred to, the speaker said that in no case had it been more than 1¼ per cent. The plates were ordered to net sizes, and came in with the usual rolling mill tolerance of ¼ in. in width, 1 in. in length, and 1 in. on the angle bars, &c. He thought it very desirable to bevel the angles at the mills, but it should not be done hot; it would be better if done cold at the fabricating station adjoining the rolling mills. In reply to Mr. Whiting, he thought the fabricating station should be set up, either at the rolling mills or in the shipyard, and that fabrication should be confined to the rectangular section of the ship. This portion, it had been found, could be produced cheaper than in shipyards.

Sir Westcott Abell, the speaker continued, had mentioned the high cost of doing the work in bridge yards, but this he said was largely in connection with the fore and aft ends of the ship, and was due to lack of experience on the part of the platers and other men handling the work. He could not agree with Sir Westcott that the cost of the rectangular portions was heavy. The failure of Chepstow shipyard was due, in the speaker's opinion, to several causes which need not be particularised, but as far as fabricated ships were concerned, some of which were dealt with on the Tees and some in the North, the National Committee on Expenditure had stated that a profit of 1,303,000*l.* was made on 14 "N" type ships. From the bridge-builders' point of view, ship fabrication was purely a war measure; they had no desire to compete with shipbuilders. As to the speed at which fabricated ships had been built during the war, the speaker pointed out that the work started six months before the Armistice, by which time the output from the bridge yards had increased to 1,400 tons per week. Had the work continued for another six months the bridge yards would have turned out a ship, or a ship and a half, a week. With regard to the large number of template makers employed by the bridge builder referred to by Sir Archibald Denny, the speaker said he thought the method a correct one if a large number of vessels were being turned out, but for a single ship it would be absurd.

The chairman then thanked the authors for their papers, and afterwards called upon Mr. E. R. Mumford to read his paper on the results of experimental research regarding "Cavitation" as affecting propulsive efficiency. This paper we reprinted on page 85 of our issue of last week.

Experiments on Cavitation.

The first speaker in the discussion which followed the reading of Mr. Mumford's paper was Mr. S. W. Barnaby, who said he did not quite agree that there were four kinds of cavitation. Mr. Mumford's No. 1 class, which depended on the air drawn down by vortices, had really nothing to do with cavitation as he understood it. Ever since the introduction of the screw propeller, vessels had been subject to screws racing through the drawing in of air from the surface; the higher the speed of a vessel the less likely that was to happen. The phenomenon, however, was quite distinct from cavitation, and should not be confused with it. Mr. Mumford's No. 2 class was what really had to be dealt with. In this case the reduction in pressure was sufficient to free air or other gases absorbed or diffused in water, together with water vapour. He thought the author's second and third classes were correct. He also inquired whether the breakdown pressure of 15·7 lb. per square inch of projected surface at a speed of 600 ft. per minute, mentioned by the author, was intended as a guide to designers, and asked what class of prime mover could be used for such large pressures.

Mr. J. H. Narbeth, C.B.E., the next speaker, agreed with Mr. Barnaby that "cavitation" had a definite technical meaning when used in reference to screw propellers, and not the broad general meaning that Mr. Mumford had given it. The speaker could understand the value of careful and costly examinations of screw propellers where there were critical conditions in high speed vessels, but there appeared to be a great field for the improvement of the propellers of merchant ships. Propellers, he believed, were designed for the ship in fully-loaded condition and proceeding at full speed, but it was quite a common thing for a tramp steamer to spend a considerable part of her time going light from one port to another. With reciprocating engines a large propeller was necessary, but with geared turbines he strongly urged an increase in the speed of revolution and a decrease in the diameter of the propeller. The propeller might not be so efficient when the ship was deep, but there seemed to be a possibility of improving the conditions under which it worked when the ship was light.

Sir Archibald Denny, Bt., who followed, said that Mr. Mumford and he had worked together on the subject for many years, and the paper was really a continuation of the address he had made to the Marine Engineers in 1915. On the subject of vibration, which had been much discussed lately in connection with reduction gearing, Sir Archibald pointed out that the method of turning the screw was not the only point. Vibrations were set up in the screw and shaft by the wake. As an instance of the effect of vibration on gearing, Sir Archibald referred to the Denny-Edgcumbe torsion meter, in which a small gear wheel was used to turn the indicating pointer. The work done by the wheel was practically nil, but the vibration and torque variations in a destroyer were so serious that the wheel had been broken by its own inertia, although it was substantially made. Continuing his remarks, Sir Archibald said it was true that the word "cavitation" conveyed a specific meaning to the minds of most engineers, but that did not bar anyone from suggesting that it meant a great deal more. The first apparatus for testing screws was a copy of that used by the late Mr. William Froude. It could not, however, be used at high speeds, and a new one was, therefore, designed by Mr. Mumford. It comprised an electric motor with means for measuring the torque, and a pair of bevel wheels to bring the propeller shaft horizontal. The thrust moved the whole apparatus backwards and was measured by means of a spring. It was a great improvement on the previous apparatus, and could be used for testing up to four screws, each being driven by a separate motor. Another apparatus had been specially designed for cavitation work by means of a stroboscope, which enabled them to see what was happening to the screw, but it had not been possible to photograph the phenomena. In conclusion, Sir Archibald invited suggestions as to how this might be done.

The discussion was continued by Mr. J. H. W. Gill, who said he had carried out a number of experiments with marine propellers, ranging from 4 in. to 24 in. in diam., under tank and water channel conditions, in the smaller sizes, and behind experimental hulls in the larger sizes. Up to the limits of his work, which, however, had not reached stage (*d*), he could endorse the statements made in the paper. In practice it was true that condition (*a*) was more prevalent than was generally recognised, and he submitted that between (*a*) and (*b*) a practical working condition might have been included, which resulted from air actually passing under the hull to the propeller. In conducting propeller experiments in still water and listening to the propeller by means of a submerged hydrophone, he had observed condition (*b*) to be evidenced by a pronounced "roar" at critical speeds much below true cavitation speed, and at immersions which precluded the drawing down of air. After explaining the reasons which had influenced the development of the integrally-shrouded marine propeller with which he was identified, the speaker said that he had been led to the conclusion that a propeller having an axially increasing pitch and contained in a nozzle-shaped shroud, of which the cross-sectional area was contracted in conformity with the pitch increase and consequent acceleration of flow, was worthy of careful investigation, notwithstanding the resistance of the shroud. The practical results obtained, he added, were very satisfactory, especially in the maintenance of thrust on low immersion and when working under conditions of high slip.

Mr. R. Williamson, the last speaker, inquired if the author had made any experiments with the setting back of propeller blades, as he, the speaker, had obtained very beneficial results by this means. In the merchant service he had found it generally desirable to increase propeller diameters and not to reduce them as had been suggested by one of the speakers.

Mr. Mumford, who was then invited by the Chairman to reply to the discussion, said he thought it would be as well to begin his paper with a definition of his conception of cavitation. He had come to the conclusion that a cavity was a cavity, whether filled with air from the surface or with air or other gases, including water vapour, from the water itself. Mr. Barnaby had instanced water vapour, but he, the speaker, had classed water vapour with other gases. With reference to the pressure of 15·7 lb. per square inch, it would be seen from the paper that the experiments were made by means of an electric motor turning a model propeller at a uniform torque in non-turbulent water. These conditions were used as a basis and were comparable with trials of ships conducted with clean bottoms, in good weather, and on a measured mile; in neither case could the conditions be maintained in practical work. The passage of air from the bottom surface of the ship, he thought might well be classed with condition (*b*). The pressure of 15·7 lb. per square inch had been obtained with an electric motor, and could be obtained with any prime mover, which gave an equally uniform torque. With the most uniform torque it was possible to get from a motor or a turbine, however, there would still be considerable variations in the pressure on the propeller blades, due to the varying speed of the wake, and this variation was of a large order. The size of a propeller, the speaker thought, was rather outside the scope of his paper, but he mentioned that he had tried a large number of angles of set-back, and had found it advantageous, in particular cases, to get the blade away from the stern-post. He had, however, found no direct gain due to set back alone, although angles up to 30 deg. had been tried. He had been very interested to hear that Mr. Gill had been able to determine incipient cavitation, and the growth of cavitation in degree by the noise produced and the speaker regarded this as a valuable contribution to the subject.

This concluded the business of the Section for the morning, and after the chairman had thanked Mr. Mumford for his paper the meeting was adjourned.

SECTION VI: WATERWORKS, SEWERAGE AND GASWORKS.

Straw Filters for Sewage Purification.

The note introducing, on Thursday, the 30th ult., in Section VI, the subject of "Straw Filters for Sewage

Purification," by Mr. E. H. Richards and Mr. M. G. Weekes, was reproduced on page 86 of our issue of last week. The discussion was opened by Dr. H. B. Hutchinson, Dr. C. C. Carpenter occupying the chair as on the previous day.

Dr. Hutchinson stated that he regarded this process as Mr. Richards' part of research work which they had been carrying out at Rothamsted on the decomposition of straw. From the bacteriologist's point of view, the case was one in which bacteria were definitely supplied with the natural requirements for their growth. In working out the decomposition of straw they had dropped upon an unusual combination of two abnormal conditions. In sewage there was an excess of nitrogen and an insufficiency of carbon to enable the organisms to develop properly. The converse was the case with straw which had an excess of carbon. If they brought these two materials together they ought to get not only a purification of the sewage, but a breaking down of the straw, since nitrogen was necessary for that to be brought about. From the first laboratory experiments confirmed these deductions and this led to the consideration of the subject from the view of sewage purification. It was not anticipated that the system had unlimited applications because of the high cost of transport of straw, &c., but it seemed likely that in small scale plants and in rural districts it might be useful. It resulted in a satisfactory effluent and produced a well-rotted organic manure of a valuable character. The results explained why market gardeners, &c., attached so low a value to sawdust manure from stables. Sawdust had a superfluity of carbon and the nitrogen was insufficient to break it down while probably its physical condition prevented sufficiently free access of air to assist the change.

Mr. H. P. Boulnois said he had tried brushwood, which was somewhat similar to the straw treatment, but it had been an entire failure. He was afraid the straw would condense so as to prevent the aeration which recent work proved to be necessary. Could the system be seen in operation on a practical scale? Laboratory experiments were all very well, but town sewage varied during the day, and in industrial towns they had to deal with sewage which contained no nitrates nor ammonia, and though it might work for domestic sewage, he had doubts as to whether sewage in bulk could be treated in this way.

Mr. A. P. I. Cotterell concurred in what Mr. Boulnois had just said. He thought the process applicable only on a limited scale and to domestic sewage. The investigators were, however, working along lines promising success, and Mr. Richards was attempting to bring back into use in an improved form the farmyard manure which farmers and others had sworn by for so many generations. Mr. Richards' work had reminded him of the late Mr. Stoddart's attempts to obtain oxidisation drop by drop. His laboratory experiments, however, did not turn out so well in practice. Could not a cheaper material be used than straw? Although there might be surplus straw at present, he thought they ought to use something cheaper for making farmyard manure. Other crops grown on sewage areas might be used for the purpose.

Mr. A. W. Bullmore said housing schemes were going on all over the country, consisting of 20 or 30 houses, and as soon as they were completed the Ministry of Health required them to deal with their sewage. In such cases the straw filter would meet a very real difficulty. They would have to overcome prejudice against using the manure on the land. People were always prejudiced against anything from a sewage farm. If this system could be used, he thought it would help small villages.

Dr. G. Fowler said he had always felt that real progress in these matters was to be made in the laboratory. They first had to find out what was possible and then go to the engineer for him to say what was practicable. He had lately published a paper on the conservation of nitrogen with reference to activated sludge and the lines he had suggested were similar to those which Mr. Richards had taken up. In activated sludge it had been possible to precipitate out all the colloidal nitrogen but there still remained the nitrogen in solution. The Chinaman had for centuries solved the problem by means of fish ponds. The same system was used on a large scale on the Continent, notably in Berlin. The nitrogen was precipitated as fish. That was only possible where one had a body of clear water. It seemed to him that with activated sludge one got a well aerated effluent which might be used for fish ponds, since irrigation was inconvenient in this country for so much of the year. Could they use something cheaper than straw in Mr. Richards' system? He thought all they wanted was a readily fermentible carbo-hydrate. He thought only the softer portions of the straw would be attacked, and, wherever there were effluents from sugar factories or distilleries, they should be added. In wood pulp manufacture there was a lot of finely-divided waste which might be utilised, and should provide a highly nitrogenous manure.

Mr. R. St. George Moore, said he had come across a method of sewage disposal in China which consisted in setting the sewage in large earthenware tubs and allowing it to putrefy to a certain extent, and then using it on the market gardens. That, of course, was the sewage of a vegetarian people.

Dr. Fowler admitted the difference between European and Chinese sewage, but the reactions were similar. In Calcutta he had allowed for the septic tank treatment of 5 gallons per head. After 3 days it was almost free from smell. In European sewage there was more nitrogen. There was no fundamental difference in the question of its application to the land.

Mr. J. D. Watson thought the experiments had been well worth making and in some cases the method would be extremely valuable if well managed. Twenty-five years ago he had been called in to deal with the sewage at Balmoral Castle. They were then using straw, so that the idea was not new, but the management was bad and the system gave trouble. It was regarded as complicated. The difficulty of obtaining straw would sometimes be serious, especially in a year like the present.

Mr. Richards, in reply to points raised, said the only substance cheaper than straw which he had so far experimented with was bracken, which unfortunately was very refractory, and he had not been able to secure any recovery of nitrogen worth speaking of. Time had been wanting for further work. All the work done so far had been carried out through the generosity of Lord Eldon, who had met all the expenses. It took from 10 to 14 days for the straw to be thoroughly activated. The optimum temperature was about 35 deg. C., but at 60 deg. F. to 70 deg. F. the process was successful in 10 days. At the end of three weeks the straw was loaded with as much nitrogen as it would take up. There was no danger of choking the straw, which retained its strength and tubular character. Only 20 per cent. of the available carbon disappeared in the process. Afterwards it went on rotting till 50 per cent. had disappeared, though none of the nitrogen was lost. Straw consisted of 20 per cent. starch and 80 per cent. cellulose of various types. The latter was not easily attacked, but was acted upon when on the slip and not in the filter stage.

The Wainfleet plant was now well past the experimental stage. No skilled supervision was employed in the bio-chemical sense. He considered town sewage containing 10 per cent. to 20 per cent. of ordinary trade effluents could be treated. The prejudice of holders against using straw manure had certainly to be overcome. People used animal manure but would not use human manure for some reason. With activated sludge a perfectly clean effluent could be produced which, if passed through a straw filter, could be made to give up all its ammonia. In one case a trade waste containing 40 per cent. of carbo-hydrate and no nitrogen had been treated, and the sludge from it improved from 1 per cent. of inert matter to 5 per cent. of very available nitrogen. The question of straw had to be considered. Last year there was a superabundance in the eastern counties. This year there would be less and the price would go up.

Activated Sludge and De-watering Sludge.

The next subject taken was "Activated Sludge." The note introducing this, by Mr. John Haworth, was reprinted on page 86 of our issue of the 8th inst. Immediately following, Mr. J. D. Watson presented a note on "De-watering Sludge," which was also reprinted on page 87 of the same issue. The two subjects were discussed together.

Dr. G. J. Fowler opened the discussion, stating that he could claim to have first suggested the use of diffusers for the activated sludge process; the whole subject had been gone into in his laboratory at Manchester. Small orifices were to be avoided. At Worcester he found they had no difficulty with diffusers except from rusting at the point where the iron joined the porous plate. That, he thought, might be got over. In the United States scarcely anybody was using anything but diffusers for introducing the air. In the early stages nearly everything had been tried. Pipes with small orifices acted differently. One could not always keep air pressure in the pipes and small particles got in and clogged the openings. All sludges were not the same though they looked so. Originally it was thought the activated sludge process was dependent upon the action of certain worms. The prime mover, he thought, was first of all acids secreted by certain bacteria and causing a clotting of the sewage, and for the rest was mainly the action of bacteria.

In the Federated Malay States he lately recommended experimentally, in the case of some isolated bungalows, a tank something like Mr. Haworth's but without paddles, the discharge coming down straight on to the surface of the water and so setting up movement. Mr. Watson stated that fresh humus was the same as activated sludge. He did not agree with that. In a percolating filter there were things not in activated sludge, such as larvæ, algæ, &c. If one looked at a portion of scum from a percolating filter the outer layer was well aerated, but the inner layer was black. That led to moving it about, and ultimately to the activated process. Then with regard to the amount of sludge, was it the same, or less, in the activated process as in others? Mr. Watson, to get his final quantity, had to add together the amounts from all his tanks. He was interested in what Mr. Watson said with regard to working for a minimum amount of sludge. It really depended upon whether one was working or not for a fertiliser. If one wanted the least possible amount of sludge one would push matters to such a length as to use up a lot of the nitrogen. Mr. Watson's aim had been to reduce sludge to a minimum regardless of its nitrogen value. Even in the tropics the land did not always require as much water as was necessary to carry the sewage, and the land might suffer from waterlogging under sewage disposal irrigation. Therefore it seemed to him that if the nitrogen could be preserved and only a clear effluent left to dispose of, the solid sludge could be put on the land, as and when needed, in the dry state. He thought that the better system, though it might require more plant in the initial stages.

Mr. A. J. Martin said that in this discussion a great deal had been heard about aeration and agitation, as if the two things were distinct. In the Sheffield experiments agitation was maintained by aeration. The crux of the activated process was the enormous quantity of air required. At St. Albans in some experiments it had been found that about twenty-two times as much air was required as was really wanted for the oxidation of the organic matter present. At Worcester, with weaker sewage, something like six to seven times the amount was needed. Most of the efforts at the present time were directed to reducing this amount of air.

In discussion with Dr. Fowler, the latter had pointed out that the changes going on were not merely chemical but were concerned with life processes which might take much more air than was seemingly necessary for oxidation. It would ultimately, he thought, be found possible to reduce the air taken. Agitation could be effected by other means. He suggested a long horizontal closed cylinder might be tried in order to prevent the usual escape of air at the surface. In this cylinder the air would not be allowed to escape, nor the sludge to settle. With regard to de-watering, if heat were used, after heating to a certain point the organisms and the colloidal matter were

affected, so that the material parted with its heat much more readily. In 1900 he had carried out some experiments which he regarded as of little value at the time. In a septic tank at Exeter he had found sludge at the top to contain 80 per cent. moisture. In the middle it contained 83·9 and at the bottom (4 ft. depth) only 80 per cent. moisture. He thought that might point to the use of towers 20 ft. or 40 ft. high for settling the sludge so that the water of the bottom portion might be driven up, so reducing the bottom sludge to a suitable condition, practically solid and without fluid, and therefore saleable. He thought, however, that de-watering was not the right direction to work in. The product was costly to transport. It was much easier to deliver a liquid or slippery solid by means of a pipe, and he thought Mr. Clifford's work at Wolverhampton on these lines was of interest. Mr. Clifford was delivering sludge by pumping to adjoining landowners.

Mr. W. Clifford asked what proportion of the sludge Mr. Haworth allowed to go into the agitation channels and what proportion of the total was allowed to pass. Was a large proportion of the sludge removed to be dealt with, not by aeration, but in the ordinary way? Did the 1½ ft. per second mean the average velocity in the channels? Some fifteen to twenty years ago they handled sludge, carting it away to farmers at a loss. Later, on looking into the matter he found the farmers usually wanted the sludge at certain seasons only, but were actually manuring their fields seven or eight months in the year. They had no storage accommodation, however. They were quite willing to take sludge over this period, but could not spare the carts, &c., for it, except during frosts, &c., so he (Mr. Clifford) proposed to deliver it by pipe. The experiment was tried first on their own farm, the sludge being delivered at the rate of ¼ acre to ¾ acre per day, and distributed fairly evenly. Larger crops were grown and the adjoining farmers asked to have fields done. They ultimately decided on 4-in. pipes, and found that all their sludge could be disposed of within a radius of 900 yards of the plant with a four years' rotation. The difficulties with regard to laying the pipes had been got over. They could lay a ¼ mile per day. With regard to de-watering he had tried de-watering ordinary sludge with lime, air dried under sheds, but the time of drying was prohibitive.

Mr. Coombs said he had never heard any complaints with regard to diffusers. Small pores or orifices should be avoided, but if working was continuous, air was in them and not sewage, and there was no trouble. If the work were intermittent the air would be forced out and liquid would flow in and organic matter would collect inside. This would have to be dispelled by blowing extra air through at the start and in a short time the diffuser could be got back to its original porosity. If one were only working intermittently at long periods some of the smaller pores did choke. Mr. Haworth seemed to think the air solution at the atmospheric surface was more serviceable than bubbling from below the tank.

There was a great difference between a laboratory test vessel 6-in. deep and the tank at Worcester 18 ft. deep. Dr. Amstey had shown that the rate of solubility was more or less proportionate to the pressure. In the laboratory vessel the time of contact of a bubble with the solution might be one-eighth of a second compared with 6 sec. to 9 sec. at Worcester. Paddles and screws carried a large amount of air with them into the sewage which went rather against Mr. Haworth's argument for the surface action. The amount of air taken into the tank was a big factor. In Chicago, at Packingtown, as Mr. Langdon-Pierce had shown, 6·6 hours were required for aeration with 3·5 cub. ft. of air per gallon of sewage treated. At Milwaukee with four to five hours aeration only, 1·5 cub. ft. were used. The two factors of volume of air per gallon and time of aeration seemed to be proportional to the strength of the sewage.

Dr. Calvert said activated sludge had to be regarded as a generic term covering many varieties of sludge. They could work the system in varying cycles according to the result they desired to achieve, whether they wanted to produce more sludge or to avoid its production. Did they get a drier sludge with a deep tank? Some of Mr. Martin's remarks suggested that they did. He had not found it possible to determine that.

Mr. A. W. Bullmore asked whether Mr. Haworth could give any idea of the state of the liquid before it got into the Dortmund tanks he had referred to, relative to Royal Commission requirements. Could Mr. Clifford give them any idea of the quantity of sludge he put on the land; he assumed the land was left fallow for at least a year so that he got his four years' rotation of crops. Mr. Clifford replied that 40,000 gallons of sludge were applied per acre and that generally only arable crops were irrigated, but sometimes grass crops were treated.

Mr. E. H. Richards said one of the questions which he had been asked to investigate for the Board of Agriculture was: What was the source of the extra nitrogen in activated sludge over and above what was contained in ordinary sewage sludge? They found that generally, in the case of sludge produced by diffuser action and not by agitation, it could not exceed 7½ per cent. of the total nitrogen. Activated sludge contained at least twice as much nitrogen as sludge produced by the ordinary methods of tank treatment, when they were both compared in the wet state. It was found that the excess of some 3 per cent. of nitrogen in activated sludge over and above that which was found in the ordinary type of sludge could be accounted for to the extent of at least 50 per cent. by the bodies of the protozoa, which constituted a very large portion of the total population of a well-matured activated sludge. Something like 1,250,000 living protozoa of all types were found in 1 c.c. of activated sludge containing about 98 per cent. or 99 per cent. of water; and from a quantity which was vouched for by Mr. Cutler, the protozoologist at Rothamsted Experimental Station, they were able to say that the nitrogen contained in those protozoa alone accounted for 50 per cent. of the additional nitrogen for which they were looking. He thought that the difficulty which was found in handling activated sludge from the point of view of de-watering it was simply due to the fact that so much of the solid matter in the sludge consisted of the bodies of living organisms, the gelatinous protein which constituted the greater part of their cell structure being probably one of the most difficult things to de-water.

Mr. Haworth, in replying, said with respect to the small orifices, he gathered from Dr. Fowler that he thought the small pores would fill up, but larger holes would not. He (the speaker) had tried using perforated metal plates, boring holes of various sizes in brass plates, and using those for the purpose of bubbling air through; but he still found with the Sheffield air and the Sheffield sewage there was a clogging effect; and, further, when the hole was sufficiently large to prevent serious clogging, in the course of, say, a few months, they found that the quantity of air used would be such that it would be quite uneconomical. Dr. Fowler had mentioned that the Americans were using porous diffusers and had not complained. His information, however, went to show that they did experience choking unless the air was washed. He understood that it was proposed to put down a somewhat elaborate plant at Milwaukee for washing the air before passing to the diffuser. That would mean a rather serious addition to a sewage plant, particularly if it could be avoided. The whole question with him was: Was it necessary to have the air in small bubbles?

Dr. Fowler had suggested that the Sheffield brand of sludge was not activated sludge. It was sufficient for him personally to know that the particular brand of sludge they had in Sheffield purified the Sheffield sewage, and he was quite prepared to find that the sludges taken from different parts would be of different character. He had also found that in the sludge at Sheffield the particular types of organisms varied from time to time according to the weather, according to the conditions, and according to the trade waste that was entering; and he could quite understand that the bacterial population of the sludge would vary in character from time to time and in different places. If this sludge, whatever its brand might be, purified the particular sewage one was dealing with, one need not trouble whether it was like the sludge in Worcester or Manchester or Sheffield, or any other place.

He might say that he found when the water content of the sludge was reduced to about 80 per cent., then the sludge very readily parted with water. As he had mentioned, he had been experimenting with the drying of sludge on papermakers' gauze, and the water content could be reduced from, say, 98·5 to from 75 to 80 almost instantly. Then that sludge, with 80 per cent. of water, when exposed to the air very readily parted with its water. With the large tank, which he had briefly described and which, as he had said, was treating from 500,000 gallons to 600,000 gallons of sewage per day at the present time, and in times of storm volumes running up to over 1,000,000 gallons per day, they had a catch-pit capacity of 20,000 gallons, and the quantity of sludge entering the tank ordinarily amounted to about 20 or 30 parts per 100,000. Of course, the quantity in the sewage varied from time to time according to the weather. With respect to velocity in the channel they had measured velocities over sections of the channel with tubes, with current meters, and with floats of various kinds, and the 1·5 ft. per second was the mean velocity over a section of tank taken at several points in the tank. Mr. Bullmore had asked what was the state of the liquid when it entered the Dortmund tank. The liquid was a purified liquid; it simply entered the Dortmund tank for the purpose of separating the sludge from the purified liquid. If one allowed it to stand for a few minutes there would be a perfectly purified clear liquid separating from the sludge; and that liquid, in the case of the Sheffield experiments, would be well within all the River Board and Royal Commission standards.

Mr. Watson said they ought not to lose sight of the fact that the duty of a local authority was to get rid of sewage and to get rid of sludge at the least cost without nuisance. The question of getting rid of sludge had been effectually dealt with in London, in Manchester, and in Glasgow, by taking it all out to sea and dropping it into the sea. But in doing that one lost the nitrogen, which ought to be used for the benefit of fertilising growing crops. But so far as the efficiency of the work was concerned he did not think that any method could be better than that of taking it out to sea. On the question of cost, he had found that the cost of taking it out to sea was about 5½*d.* per ton, and that was the cost as nearly as possible of dealing with the sludge at Birmingham. That, of course, was a pre-war figure: it was 5·7*d.* in 1915; it rose to 6·5*d.*, until in 1921 it was up to 16*d.*, and the average for those years came to 10*d.* per ton. That was not an unreasonable cost, and if one could get rid of it at that cost, with the sludge, as they had at Birmingham, in a condition which was capable of being utilised as a fuel, then they had gained something. It was also capable of being used as a fertiliser, because they ought not to forget that after the sludge had gone through that digestive process it still contained 2½ per cent. of nitrogen.

A method had been tried at Bury and the analysis which had been produced of the work done there certainly led one to feel that it was worthy of consideration. It was certainly simple. They had there what one would call an upward flow-tank, which was formerly called a Dortmund tank, with a cylinder from the top to the bottom. At the top they had means of throwing the sludge out. By this scooping arrangement they threw the activated sludge out and distributed it over the surface of the tank. That activated sludge simply precipitated to the bottom again, and the circulation went on for a considerable time. From the analysis the process was an efficient one, and as far as he could see it was the cheapest mechanical arrangement that had yet been introduced.

They knew now that the very best that could be done by a septic tank was the reduction of the sludge to the extent of 33 per cent. or something like that, and that was got rid of by the digestive process. The Birmingham sludge was pumped five miles before it reached the drying area, and, as he had explained in the note there was practically

no more difficulty in pumping that sludge than there would be in pumping clean water. Mr. Martin and Dr. Calvert had made a reference to the fact that, by depositing sludge in deep tanks one could, in that way, get rid of a good deal of the water. He (the speaker) had tried an experiment of that kind and had found that it was so. But he had obtained no benefit from a tower which was constructed for the purpose, beyond the depth of 13 ft.; that was to say, at 13 ft. deep they got a sludge which had about 75 per cent. of water in it, and below that depth they always got the 75 per cent., so that he had rather come to the conclusion that that was the maximum depth at which any special benefit could be obtained.

This terminated the proceedings of this section on Thursday, the 30th ult.

SECTION VII—ELECTRICITY WORKS AND POWER TRANSMISSION.

ELECTRICAL DISTRIBUTION.

At the meeting of this section at 10 a.m. on Thursday, the 30th ult., two papers were down for reading and discussion. These were "Economic Limits of Distribution from Coal-fired Stations," by Mr. W. B. Woodhouse, and "Low-Voltage Overhead Distribution," by Mr. B. Welbourn. Owing to a mistake, in the printing of the programme, the first paper had been put down for the Friday meeting and Mr. Woodhouse was unable to alter his date for attendance when the mistake was pointed out. As Mr. Welbourn was also not present at the opening of the meeting, the two papers which were taken together, were read by Mr. H. R. J. Burstall, the Hon. Secretary to the section. The second paper was reprinted on page 87 of our last issue, and the first will be found reprinted on page 128 of this issue.

The discussion was opened by the chairman, Mr. Roger T. Smith. Referring to Mr. Woodhouse's paper, he said there was a statement at the end that, "Broadly speaking, however, the comparison on the basis taken shows equality of cost between cases 1 and 3 when the distance between stations is approximately 30 miles." That was an important figure to the railwayman, because it meant that it was more economical to generate current than to purchase it if the capital power station was more than 30 miles away. Parliament seemed to have had in its mind in the Electricity Act that railways should have the opportunity of buying in the cheapest market. They might, of course, buy their electricity from a joint electricity authority, but in cases where the generating station was too far away from the railway, then under the Act a railway company could ask the Commissioners for approval to build their own station. There was, of course, always the important consideration for the railway company that by purchasing current it saved a very large capital expenditure and, incidentally, saved the troubles that came from adding another grade of workmen to its staff, who had unions of their own, which were not connected with the railway union.

Mr. Paignton, speaking with regard to Mr. Welbourn's paper, said the principle of applying an ice loading in the calculations, in a country like this, was entirely the correct course to take. The old Board of Trade regulations took moderate weather conditions and a fairly high factor of safety, the idea being that in certain cases the conditions might be more severe than the conditions taken as the basis of the regulations, leaving the factor of safety higher than that at which danger was to be feared. Although that appeared to be a fairly reasonable thing, it did not work very well in practice, for the reason that if an ice loading occurred, the factor of safety in a large conductor was not reduced to such a great extent as with a small conductor. Large conductors, therefore, laboured under a handicap.

Where it became necessary to use small conductors consideration should be given to a form of conductor not yet used to any great extent in this country, namely, the so-called steel core aluminium cable, in which the outer wires were of aluminium and the centre of high-grade steel. As regards lines in sheltered positions, he thought it would be generally agreed that the regulations should be modified compared with overhead lines laid in open country. He had heard it suggested that for sheltered conditions an ice loading of $\frac{3}{8}$-inch radial thickness, and a wind pressure of 8 lb. per sq. ft. should be adopted, and he thought these were reasonable suggestions.

Mr. B. Welbourn, who had entered the meeting after the reading of his paper, said he had always believed that overhead low voltage distribution had a very definite place in the development of electric supply in this country as a stepping stone during the period when capital costs must be kept low. There were many outstanding questions of interest as, for instance, the question of permissible voltage in crowded thoroughfares on overhead wires. There was a good deal of experience, particularly in Canada, and the United States, with 2,000 volts or 3,000 volts, overhead conductors down crowded thoroughfares, and he did not see how we were to deal with the loads in this country without raising pressures. Some people might say that if pressures were to be raised underground cables should be used. That was one of the matters which required discussion.

Another difficult matter was how the services should be taken to individual houses from the overhead wires. There was a good deal to be said for using an insulated cable from the nearest pole to the house. In many cases lead-covered rubber cable was used for that purpose, but linked up with this was the question of lightning protection. Personally, he had never known of a case of lightning being conducted into a house from an overhead line, but an instance had been brought to his notice which suggested that it was possible. It was, however, possible to use a short length of lead-covered rubber cable, which would prevent effects from lightning, and that was a method which had been used with outstanding success in terminating high voltage lines, and if adopted, might almost entirely eliminate any risk of lightning troubles in the house.

Mr. G. V. Twiss said lines erected in sheltered positions were likely to be particularly adversely affected by snow and ice if the conductors were small, and he felt that for such lines it was necessary to have a limit on the minimum size of conductor to be used. Against that, there was the fact that for low tension work there were switch wires and other wires, for which it was generally found economical to put up the smallest gauge, say 8 or 10 S.W.G. Looking at the matter generally, it seemed to him, in regard to wires in sheltered positions, that a half-way line between the Post Office practice and the existing Board of Trade regulations, would be the better course to follow. Mr. Welbourn had referred in his paper to the question of standardisation and the B.E.S.A. specification for telephone and telegraph line material. This specification called for Cordeaux screws, but these were not at all good mechanically, so far as he could see from tests which he had made, and they were very bad electrically, although that did not matter very much in low tension work. Therefore, it seemed to him necessary that there should be two types of insulators for small wires and large wires, and that it would be bad practice to have Cordeaux screws in conjunction with power lines at all.

Mr. S. G. Leech said that he had found that the question of whether conductors should be stranded or solid was entirely a constructional matter. It was possible with a 000 or a 0000 solid conductor to get a satisfactory appearance, although there was a risk that in straining up and making off at an insulator they might get a kink. A reason why they should not go beyond that size with a solid conductor was the difficulty of getting rid of the wave, which was given to the conductor by being wound on the drum. With regard to weather-proofing wires with two or three wrappings of some tape and compound, in two or three years this material was usually found hanging in festoons from the wire, and gave a very untidy appearance, and he doubted if it added two years life to the cable. Given a good atmosphere, a No. 8 iron wire constructed of the old Swedish charcoal iron and galvanised, would last for 20 to 25 years, and he had records of a Silesian bronze wire No. 14 which had a life of 15 years.

The height of wires above ground was a controversial matter, and he had never been able to find a reason why the Board of Trade had fixed the limit of 22 ft. He held the opinion that 17 ft. to 18 ft. was high enough to clear any possible obstructions from traffic. With regard to Post Office methods concerning guarding, he had found the Post Office people most reasonable in certain cases, and where they had been shown that the guard wires would be objectionable they had consented to insulating their own wires where they crossed the power wires. They used a wire in that case covered with what was known as P.B.J. compound. Cost, of course, was a vital question, and he noted that the author put the cost of overhead work at 20 per cent. higher than underground. He had worked out figures himself before the war for one or two cases of distribution systems, and found that if one complete system was compared against the other, *i.e.*, including feeders, distributors, street lighting, services, &c., a saving of 40 to 50 per cent. could be effected by using overhead distributors.

Apparently, Mr. Welbourn considered that eventually everything would go underground, but personally he was strongly of the opinion that the only possible means of giving a sufficient supply of electricity to rural areas, large villages and smal towns, would be by overhead mains. He did not think that the Post Office practice afforded a true analogy, because the largest iron wire they used was No. 8, and the largest bronze wire was No. 14. Consequently, with the exception of the switch wires in a distribution system, the Post Office had to deal with very much smaller wires, which would come down more readily than would overhead conductors for distribution purposes. He remembered having a very interesting chat with Sir William Slingo on this matter on the occasion of the great storm of 1916. Sir William Slingo told him that if a line were drawn from a point somewhere near Flamborough Head to South Wales, that represented a belt, to a certain distance on either side, which was devastated by severe storms once every ten years, according to the records which the Post Office had.

Mr. S. C. Bartholomew said the difficulty with low-pressure overhead lines was the sag in dealing with wires of smaller gauge. To get over that difficulty an endeavour was being made to draw distinction, as far as factors of safety were concerned, between low and medium-pressure lines, and high-pressure lines, but it was found to be a difficult matter to arrive at a basis for the difference. He could not agree that towns and places where low pressure overhead wires were required could in any sense be called sheltered, and an important point to be borne in mind was that the regulations were for the safety of the public primarily. With regard to the ice factor, the old regulation was based on half an inch of ice, but he had records of 5 in. to 8 in. of ice on a wire, and very often the accumulation of snow on a wire in a sheltered position was greater than that in an exposed position.

The Post Office wires were not put as high as 22 ft., except when crossing roads, and they always had to bear in mind the possibility of haycarts on country roads with loads which might come into contact with wires which were lower. Tramway wires were usually 21 ft. or 22 ft., and that was possibly the basis for the height of overhead wires in the Board of Trade Regulations. As to insulating Post Office wires when crossing power wires the Post Office was always prepared to put up P.B.J. covered wire if the conditions allowed. With regard to the effect of lightning from overhead conductors, the Post Office experience was that the ordinary lightning protector was sufficient to protect houses from this danger. The decision of the Post Office to go underground had been a gradual process now for some years. It must be remembered that the National Telephone Company, owing to the conditions of its lease, had no incentive to provide underground wires, with the result that the Post Office was left with a legacy of overhead lines, which, under other conditions, would not have been erected by the National Telephone Company. The P.B.J. compound which had been referred to was a thin layer of insulated paper covered with a braiding soaked in red lead.

Mr. A. H. Preece, referring to Mr. Woodhouse's paper, said that people were rather apt to talk in a casual way of the 500,000 kw. power station. In

this country such power stations were very difficult to arrange. There were the water and coal questions to be considered, and there were very few sites in this country where such stations could be justified when compared with putting up, say, three 100,000 kw. stations at different points as against a 300,000 kw. station, or, say, three 200,000 kw. stations as against one 600,000 kw. station. A power station with an output of 500,000 kw. required something like 5,000 tons of coal a day, and something in the nature of 10,000 cubic feet of water per minute for condensing purposes. In one case the water amounted to 30,000,000 gallons an hour, and there were not very many rivers where that quantity would be available. Again, in regard to coal, it was necessary to keep two or three months supply in hand, and, as a 500,000 kw. station necessitated the handling of 5,000 tons of coal per day, it meant that something like 200,000 tons of coal had to be stored.

Again, Mr. Woodhouse assumed a load factor of 60 per cent., but he did not believe that such a load factor could be looked for. In Manchester, which had a fairly concentrated industrial area, the load factor was only 32 per cent., and he did not see any hope of getting that up to 60 per cent. He knew of only one case, and that was abroad, in which the load factor was 46 per cent., and that was a big station, turning out 150,000,000 units, and where there were no eight-hour shifts, no Saturday afternoon or mid-week football, and no Sunday closing. People worked practically 12-hour shifts night and day, in the factories and mills, and then the load factor was under 50 per cent.

Mr. Ll. B. Atkinson, in reference to Mr. Welbourn's paper, said that his experience with overhead distribution was not very wide, but some years ago he was interested in the development of the Trafford Park industrial area and the development there was undertaken with overhead wires at first, purely as a tentative measure. The overhead distribution was of a type that could be removed easily if necessary and the Board of Trade was very ready to allow a lot of experimental work without any mention of regulations. Still, with all the conditions in their favour, the whole of the distribution had since gone underground. It was true that the area was a small one, about 3 miles long by ½ of a mile wide and that lent itself to a straightforward underground system, but the fact remained that they found no inducement to keep the distribution overhead.

Mr. Welbourn had raised the question of whether we should stick to 240 volts or go boldly to a higher pressure. His own impression was that we should go to the higher pressures on overhead lines and have transformers on consumers' premises, rather than do what had been done in Hereford, and have transformers at intervals on the poles serving a definite area. There had been a good deal of experience with 500 volts with tramways and there had not been any number of fatal accidents. Moreover, if we were going to have 500 volts we might just as well go to 2,000 volts, because both were dangerous if one came in contact with them. He had been interested to notice during one of the Institution of Electrical Engineer's visits to Holland, that there was plenty of overhead work there. Indeed, it was a little surprising to find high pressure lines going to the farms—5,000 to 10,000 volts—and an arrangement whereby even the man with a threshing machine could hitch on to a high pressure line with a sort of hook attachment and connect up to his threshing machine.

Speaking of factors of safety, he thought that all this discussion about half an inch of ice was really beside the point. If they were going to put up overhead lines so that they would stand up to anything in the way of weather, they would be prohibitive right away from the point of view of cost. Mention had been made of the storm of 1916, and on that occasion he happened to be staying with Mr. Woodhouse, and he went out with him to see some of the Yorkshire Power Company's poles. Somebody had spoken of 5 in. or 6 in. of snow. A good many of the Yorkshire Power Company's poles were down on that occasion, and they had 2 in. of ice and it was no use speaking of ½ in. of ¾ in. of ice. They would have to contend with a great deal more than that, and it appeared to him that it was necessary to make up our minds when going in for overhead lines that some of them would come down occasionally. Not long ago he had had a conversation with Mr. Hobart and was surprised to hear that he had always to keep a stock of candles in the house in his home in America, notwithstanding that he was supplied with electricity from one of the large power companies there. Mr. Hobart said that the supply was frequently interrupted for half an hour or so at a time through something going wrong with the overhead lines or else in the power house. These were conditions we must bear in mind when considering overhead lines in this country. We must realise that they would come down sometimes and it became a question of having a supply under these conditions in districts which would not otherwise have a supply at all.

As to lightning getting into the houses from overhead conductors, he had heard of a case in Buckingham where the supply was given by the Chesham Company, and the owner of the house said that the lightning jumped all the switches though they were open and broke all the lamps in the house. Exactly what form of discharge that was he did not know, but here was a clear case of lightning having struck a house through the use of overhead conductors.

Mr. W. A. Turnbull said he thought 500 volts for overhead distribution would be about the limit. At the same time, in connection with tramway work he had not known a workman to be killed by a 500 volt shock either in the station or on the line during repair work. The deaths from repair work on tramways had always been caused by the men falling off the tower wagon after receiving the shock. In dealing with a housing scheme and using overhead wires, he had proposed to run the wires overhead from the chimneys and run them into the ends of the houses, protecting from contact with persons by a barbed wire ring similar to the way in which high tension poles were protected. The overhead wire scheme had, however, been abandoned.

Mr. McEwan said a point in connection with the use of weatherproofed wires was the possibility of fire spreading as a consequence. After a while, with the wear of the covering, the wires became covered with a kind of cobwebby compound which, if it got alight, carried the flame very rapidly. He had such an experience a few years ago.

Mr. A. H. Preece, speaking again, said he thought the use of weatherproofing was adopted because some people had a feeling of greater security in consequence. In America and some of our Colonies weatherproofing was insisted upon, and he believed that the insurance companies in the Argentine would not approve of bare wires in the streets for alternating current purposes. In this country it might be that a certain number of people would be happier if they saw a little bit of covering on the wires, and it might be necessary to meet their wishes. As to the weatherproofing material fraying, this covering was used a good deal in New Zealand, and an engineer there had told him that the material he got from America lasted 10 or 15 years, whereas the British material only lasted five or six years. The matter had been looked into here with the manufacturers, and it was found that the Americans were using a cotton braiding with a special compound rubbed into it, whereas the English manufacturer used jute. He had, however, recently obtained wires from British manufacturers cotton braided, and he hoped they would last as long as the American.

Mr. G. V. Twiss, also speaking for a second time, said he did not think that the American transmission lines referred to by Mr. Atkinson should be taken as characteristic of the behaviour of overhead lines if properly designed. One of the causes of trouble in America was the use of insulators which were not good. American porcelain insulators certainly did deteriorate very badly, the chief reason being that they were not vitreous. Lines which were fitted with insulators made by British porcelain manufacturers did not shut down in the way that Mr. Atkinson had indicated. In connection with the Victoria Falls supply there had been many shutdowns through faulty American insulators, but since they had insulated one of their lines with English insulators there had been no shutdowns whatsoever. The Waihi Gold Mining Company had been in operation for four or five years using English insulators, and there had only been one shutdown during that time. Ice loading was a very useful method of calculating out the stresses on transmission lines consistently, because the sags were very similar under the influence of ice to what they were under the higher temperature conditions of the summer. Consequently, the worst summer trouble, would be very similar to the worst winter trouble, and thus ice loading became a consistent and logical way of calculation.

Mr. Matthews suggested that there were many rural districts in England which would be only too glad to have a supply from overhead wires even with the prospect of being cut off for half an hour now and then. He was amused to hear that weatherproofing had been a dangerous thing from the point of view of fire because in the danger buildings of Woolwich Arsenal this type of cable was put up as a protection against fire.

Mr. Welbourn, replying to the discussion, said that in Canada and in the States the chief object in putting weatherproofed wires up was to give some sort of sense of security to the linesmen, but in a report on the subject by a Canadian committee of engineers there was a very great division of opinion, and roughly half the committee were in favour and half against the use of weatherproofed wires. Reference had been made to the belt across England known as the danger zone. He did not think it was quite as wide as had been suggested. It was better defined, he believed, by drawing a line from Lincolnshire down to Harwich and then taking a V down to about Swansea. The railway companies as well as the Post Office had a bad time in this area. Sir William Slingo had stated that the Post Office had 35,000 poles down in the storm of 1916, and he understood that the railway companies had approximately 3,000 down. No fewer than 6,000 of the Post Office poles were broken.

As to the height of wires, he had looked up the Board of Trade regulations and found the minimum was 20 ft. for tramways, with such variation as the Board of Trade might allow, so that there did not appear to be any consistent practice. The Lancashire County Council permitted wires to be erected across their roads at 16 ft. 6 in. He had never heard of a hay cart being loaded to a height of 20 ft., and 17 ft. 6 in. was abnormal, so that there appeared to be no justification for 22 ft. which conflicted with the 20 ft. for tramways which had always been found to be sufficient.

The meeting then adjourned until 10 a.m. on Friday, the 1st inst.

SECTION I.—RAILWAYS, ROADS, BRIDGES AND TUNNELS.

Impact Tests and Allowances.

On Section I of the Engineering Conference reassembling on the morning of Friday, July 1, Mr. W. B. Worthington again occupied the chair, and the adjourned discussion on "Impact Tests and Allowances" was first taken. The first part of this discussion was reported on page 50 of our last issue, and the note introducing the subject by Mr. Fereday, reproduced on page 80.

Major G. L. Hall, said Mr. Fereday had not mentioned the recent tests made by the Ministry of Transport in connection with the revision of Board of Trade requirements. The Pencoyd formula was suspected of giving figures too low for short spans and too high for long spans. Twenty-five bridges were tested, all of steel, some ballasted and some unballasted, but all representative of modern practice. Some 362 records were taken, particular attention being paid to spans of 40 ft. and under. Speeds up to 84 m.p.h. were recorded, but the average of 60 m.p.h. to 70 m.p.h. was worked to. The following deductions were made: (1) There was much less difference in the impact effect on ballasted and unballasted bridges than was supposed. (2) A very marked difference was found between the observed static stresses and the calculated static stress. (3) It certainly appeared that a very large percentage of the stress was due to the unbalanced effect of the locomotive. (4) Where the material was stressed to a very low extent by the equivalent

static load the impact increment percentage was considerably greater than when it was highly stressed; thus showing that there was not a direct and simple relation between the percentage increase on live load and the span in feet. (5) The analysis of the diagrams was highly complex and contained a very large number of vibrations at frequencies due to totally different causes.

In the main, four sets of vibrations were found. The first of these were those forced on the structure by the moving load itself. These bore no relation to the natural frequency of the structure or member, and were produced by the locomotive motion. Secondly, there were the free vibrations of the member itself, generally a function of the span. Thirdly, there were high-frequency vibrations (30 to 70 per second) or 6 to 10 times the natural frequency of the member, whose cause was the subject of some controversy. Lastly, there were the vibrations of the instrument itself, which were easily separated. The high frequency vibrations were considered to be really due to so-called secondary stresses, that is to say, deformation stresses due to the primary impact stresses in the main member measured. They were more marked for short spans, and they were included for the purpose of evolving the formula. The rectangular hyperbolic curves obtained by the formulæ

$$I = \frac{120}{90 + L}, \text{ and } I = \frac{120}{90 + 1{\cdot}5\,L},$$

respectively for single and double lines, were tentative and merely something to go on with.

Professor J. C. Inglis said that the usual empirical formula was rather disquieting, and he was glad to hear that the subject was being examined in a more scientific manner. It was very essential to keep clearly in mind the distinction between the effect due to live load and that due to impact. In the case of a smooth running load, such as an electric train, there was no doubt that the stresses in the various members tended to mount up with the speed of the train owing to being less or more suddenly generated. Only if the period of loading was a very small fraction of the free period might a serious increment of stress be anticipated. In the case of a 20-ft. span of steel joists carrying motor lorries travelling at 20 m.p.h. the increment of stress, assuming no jolting, was only about 3 per cent. or 4 per cent., and the application of load was comparatively sluggish. The great feature of the impact due to locomotives was that it was periodic, and that periodic action was apt to be destructive to the bridge. The bridge was subjected to a series of blows, giving it definite periodicities. If any of these took up the natural period of one of the members trouble had to be looked for. These synchronous oscillations took time to build up, and it would be natural to suppose they would be more apparent in long-span bridges. The formulæ produced did not distinguish between the factor for live load and the factor for impact, neither did they introduce any consideration of the nature of the load, or of the speed of the load, or the natural period of vibration of the bridge or bridge members. For these reasons it did not appear that they should command much respect. There were so many variables that these wanted separating out and tests should be made in which only one variable was dealt with at a time. A move in the right direction would be to distinguish between the influence of live load and that of impact.

Sir Seymour B. Tritton said that locomotive engineers had often been charged with not considering their problems scientifically. While there was some truth in that he would point out the great complication of the problem, and the difficulties which existed with regard to unknowns in locomotive practice. The stresses locomotives were subjected to were very largely unknown, and could not be calculated, but the effect of impact due to bad balancing was now being examined by a conference of the Standards Committee of which he was chairman. They hoped a good deal could be done in connection with Indian standard locomotives without upsetting the standards adopted. The reciprocating parts were being lightened in design and it was proposed to go further than this and use special alloys and materials.

Mr. John S. Wilson wished to refer to one aspect of the problem which was sometimes of international importance in the keen competition over the supply of bridgework for abroad. In the case of railways abroad, administrators often considered that their requirements would be met if the bridges tendered for were designed and constructed in accordance with the standard or accepted requirements obtaining in the country of manufacture. As the weight of a bridge was very greatly influenced by the impact formula the relative effects on weight of any impact formula adopted by this country and the corresponding one, say in America, was of great importance. For instance, in the case of a loaded length of 100 ft. the Pencoyd formula required 75 per cent. of the live load to be added as impact allowance, whereas the new Ministry of Transport formula only required about 50 per cent. to be added, so, other things being equal, a lighter span with corresponding advantage in competitive weights and prices would result which would be advantageous from that point of view. The point was of considerable importance, for work had been lost by this country principally through causes of that kind. He wished to put in a plea for simplicity. Mr. Fereday's note suggested that the new impact allowances would be related to loaded length. That quantity was a great nuisance, for it made the checking of designs very laborious. There was no scientific basis for it, and a formula based on it failed in the case of cross-girders and hangers where the "loaded length" had no significance. The usual stress sheet for a girder gave the dead load and live load, and a convenient impact formula should permit of the impact allowance being deduced from those figures in combination with the dimensions. Another direction in which simplicity could be achieved was by adopting what he considered was the British rather than the American method of allowing for impact. The American method consisted of taking the dead plus live load and adding a proportion of the live load for impact and then applying an invariable stress (say, 16,000 lb. per square inch) to the total to get the sectional area. The other method, and the one adopted by his late chief, Sir Benjamin Baker, in the specification he prepared thirty years ago, consisted in reducing the permissible stress in a member according to the amount of impact expected in that member. This method is quite as effective as the other, it is much more easily applied and could be extended or elaborated in the light of recent investigations.

Mr. Fereday, in reply to the discussion, said he agreed that impact was only part of a very large subject. In large spans the deformation stresses and perhaps the so-called secondary stresses, were often far in excess of those produced by impact. If any formula were produced on a more scientific basis than the present one, secondary stresses would have to be dealt with. In the case of deformation stresses a great deal could be done in putting material into adjacent members to reduce them than in the member itself to provide for them. He thought the formula of the future would be based on vibrations. It was quite true that locomotive running could not be sacrificed to bridge design. He thought locomotive builders might in the future give some sort of certificate, including a record of the centrifugal forces at various speeds as affecting permanent way and bridges. He thought the formula when evolved would not be very simple. It would have to contain a big factor for shock, and that would make it objectionable to scientific men. The subject was in the transition stage, and not at the stage where hard and fast rules can be laid down.

Road Vehicles and their Relation to Road Surfaces.

The next subject considered was "Road Vehicles and their Relation to Road Surfaces." The note introducing this was by Major R. G. H. Clements. It is reproduced on page 129 of this issue.

Major Clements, in summarising his note, said he had excluded from it the question of the power unit. The power side of the question had been greatly simplified by the tendency to increase the units of the prime mover and so minimise the vibration set up by unbalanced forces.

Sir H. P. Maybury said there were 835,000 mechanically propelled vehicles on our roads, or one to every 51 of the population as compared with 1 to 11 in the United States. The increase of the number of these vehicles made the subject of impact on roads of extreme importance. His department proposed quite soon to endeavour to get the vehicle designer into direct touch and sympathy with the road engineer so that both might work towards the common object of maintaining the roads at the least possible cost, and consequently the vehicles also. Very little consideration had been given to the question of springing. It was often said that more damage was caused to roads by vehicles running light than when loaded. With regard to tyres it was now no uncommon thing to see 18-ton tractors on rubber tyres, but these were not necessarily very resilient. As a result of the tendency to use cheap tyres the owner often obtained a non-resilient one which was hard on the road. He hoped developments would occur in the use of pneumatic tyres for heavier loads. The roads cost now three times as much to maintain as they did in 1914, and there was little hope of any reduction till improvements were introduced in vehicles, with regulations regarding the speed of the heavier vehicles and loads.

Colonel R. E. B. Crompton said he had long been convinced that it was mainly through impact that roads were destroyed. He had addressed the Institution of Automobile Engineers on the subject and had described what had been done in investigating this subject in America, with the cinematograph. It would not be an expensive or difficult matter to conduct corresponding tests here in order to obtain scales of the relative movement of parts, &c., to get an idea of the amount to which the springs were stressed and so on. The American tests had been well carried out, but he took exception to the manner in which the results had been explained.

Mr. E. L. Leeming said most engineers were up against the wave problem. He felt that road deformation was entirely due to back-axle driving. He thought experiments ought to be conducted as to the relative damage done by back axle and by four-wheel driven vehicles. The Ministry of Transport could encourage the four-wheel drive by preferential taxation. In the same way they could encourage the use of pneumatic tyres and generally encourage designers to produce vehicles which would result in less damage to the roads. They had considerable powers in that direction. The American tests were interesting as showing that the pneumatic tyre resulted in hardly any increase in impact with speed while there was a very large increase with solid rubber tyres. He would like to see the road machine at the National Physical Laboratory adapted for tests on the relative destructiveness of the back axle and four-wheel drive.

Mr. A. Dryland said the road designer had very little knowledge to go on, and no scientific data as to the stresses which would be brought to bear on the road he had to construct. Any amount of money spent on determining these stresses would be well spent. One of his commonplace assertions was that a rubber tyre in time virtually became an iron tyre. That was borne out by the diagram in the paper. With regard to heavy loads of 80 tons to 100 tons, it was not feasible to design roads all over the country to carry such loads, though short lengths might be made in particular areas. The question of springing was of importance. He thought Mr. Leeming had suggested that the direction of springing should take a forward course, not merely a vertical one. He would like to see that developed and tested. The four-wheel drive also offered possibilities, but he believed such vehicles were not looked upon with favour from a purely mechanical point of view. From the road point of view he thought the forces were better transmitted.

The chairman, Mr. W. B. Worthington, said Major Clements had divided his subject into two parts, the vehicle and the road. Speaking as a member of the ordinary public he wanted to draw attention to the fact that the very perfect condition of some roads made it possible to run vehicles which were so worn and noisy that they ought not to be on the roads at all. The road authorities ought to direct their attention to the proper upkeep of the machines

using them, if it was so desired to run them at high speeds.

Colonel Crompton said the vehicles were so knocked to pieces on the second-class roads that they were noisy on the first-class roads. The second-class roads would have to be improved before the wear and tear which caused the noise could be eliminated.

The chairman said that might satisfy the next generation, but would not ease the present nuisance. He wanted vehicles which were noisy on a perfect surface to be restricted to a low speed.

Replying to the discussion, Major Clements said he was convinced that the road designer and the vehicle designer ought to get together with some definite data to go upon. Road designing in the past had consisted largely in putting in sufficient material to make the road strong enough. The same applied to the vehicle designer who, he was convinced, had put into his machine a lot of unnecessary weight. Vehicles went along roads with a series of hops and jumps. Someone was at fault for that, either the vehicle designer or the road engineer, or both. The question of springing had a great deal to do with corrugations. A road surface could never be a cushioning surface. It was possible to get a range from a perfectly hard concrete road, and a semi-resilient asphalt or bitumen carpet. The cushioning should be provided by the wheel itself, as with the pneumatic tyre. There was a gap between the pneumatic type and the solid rubber one which might possibly be filled in the future by some other type of tyre suitable for commercial vehicles. The road engineer was the only man who had to undertake the work of designing and putting down an engineering structure without knowing what his load was, and with stresses completely undetermined.

Advantages of Bituminous Macadam.

The last subject to be taken in Section I was introduced by Mr. A. Dryland with a note entitled "Advantages of Bituminous Macadam," which we reproduce on page 128 of this issue. The first speaker in the discussion was Mr. R. J. Thomas, who took exception to Mr. Dryland's method of stating the traffic on a road in tons per yard width. He had found that on an 18-ft. country highway there was three times the amount of traffic on the central 6-ft. as on the rest of the road on either side. He thought the water-bound macadam road had gone for good. He had been laying down bitumen for eighteen years, mixing it under heat with No. 1 tar. It was mixed in a revolving drum under flame. It did not fire, and by having it hot there was considerable penetration into the slag which was used for the surfacing. The life of a bitumen road was very elastic. What was wanted was some material capable of recovering its form. He thought that when the temperature varied corrugations in some cases made some recovery. Bitumen had in itself this possibility of recovery, and that was strongly in its favour. An ordinary country road, 18 ft. wide, laid with 3 in. to 3½ in. of bitumen macadam ran to 8*s.* per yard, or 5,500*l.* per mile. In his county, with 5,000 miles of road, it would be a long while before they could put all their roads in a condition to meet future traffic.

Mr. H. T. Chapman said he thought the reason why water-bound macadam failed under modern traffic was due to lack of foundation. When resurfacing, provision was usually made for bitumen or tar concrete, and there was a good base coat as well as the surfacing to stand up to the traffic. He thought there was more accretion on the surface of tar and grit than penetration, when surface tarring. In Kent he found that 1 in. to 1½ in. of surfacing usually held the traffic until cut through or water had penetrated. He thought resiliency in both the base and surface coats was of importance. Concrete would not stand impact and had not the power of recovery under fast heavy traffic. Waviness in bitumen seemed to appear in the first six months, and then to get little or no worse for several years. He thought that might be due to the consolidating effect of the passing traffic.

Mr. S. S. Gettings said that though many engineers had taken a census of traffic their diagrams showed very little what was actually taking place as the actual loads of the vehicles were unknown. The loads varied enormously, and many mechanical vehicles were run regularly overloaded. Where there were no alternative routes, as in most parts of the counties, there was little or no choice of material for reconstruction. Concrete was ruled out at once as it was impossible to close such roads for a long enough time. In nearly every instance where reinforced concrete roads had been put down they had been tarred. He thought they ought to be allowed to go to destruction in order that we might obtain some information as to concrete as compared with the bituminous surface. Concrete could not be repaired readily, whereas a bituminous surface could easily be patched. He knew of roads put down eight or more years ago which were still excellent owing to the fact that they had no mechanical traffic to deal with them. With that traffic using the roads now, as soon as they were made up, it was more difficult to make them last. He thought the slipperiness of surfaces ought to be considered to a greater extent.

Colonel R. E. B. Crompton regretted that Mr. Dryland had not been more careful in his nomenclature. The Standards Committee had laid down that the word "bitumen" should be used to cover only materials essentially resilient in character obtained from the distillation of earth oils or certain natural asphalt, or ground asphalt. Tar products were not in this class; they had no resiliency or coefficient of restitution. The chemist had before him the problem of converting pitch products into the other. He had personally spoiled good bitumen by adding pitch to it, and good pitch by adding bitumen to it. Bitumen was much slower than elastic in its recovery, and required several seconds whereas rubber only required one-tenth of a second.

Mr. A. J. Lyddon said he had found that where the bitumen percentage of the aggregate was low it induced disintegration by the action of water to a much greater extent than where it was high. A road originally laid with 8 per cent. or 9 per cent. bituminous concrete disintegrated after three or four months, but after being carpetted with a mixture having a percentage of bitumen of 11 to 12, it had stood so well that there was no sign of disintegration to-day after a lapse of eight years. In a particular road he had in mind there were no signs of corrugations a month after completion on any portion not on concrete, while on parts laid on concrete they were very pronounced. He thought they were set up by the rolling action. In Yorkshire some 200 miles to 300 miles of road had been grouted with tar which was excellent up to a point. It was non-slippery at first, but became very slippery afterwards. He believed that when rock asphalt had reached a point at which it was not possible to compress it further, wear became very rapid. While it was capable of slight compression there was very little wear. He thought the aggregate had little bearing on the life of the mixture; it was the binder which mattered.

Mr. W. S. H. Dorman said that in the Punjab there were a few excellent roads, all water-bound macadam. The climatic conditions were unfavourable for this, and with the increase of motor traffic they were difficult to maintain. From motives of economy the made-up width had been reduced to 8 ft., but was now getting back to the original 16 ft. In Lahore, tar spraying had been tried with a view to mitigating the dust nuisance, but there were so many complaints regarding tonga ponies that they were now trying tarring the centre and leaving a strip on either side only lightly treated. He would like to know if tar concrete was more economical than tar dressing, in view of its cost to lay down, longer life, &c. In the plains in the Punjab the temperatures were very high, 180 deg. to 190 deg. F. sun temperature, and he would like to know if asphalt would stand that. He had found difficulty in getting a definite answer. In India there was very little coal tar, and tar macadam was out of the question. He thought in spite of disadvantages it might be necessary to resort to concrete roads. There ought to be some intensive method of testing road surfaces to destruction. Fifteen or twenty years was a very long time to wait to see what would happen.

Major-General Sir G. K. Scott-Moncrieff thought that it was important that the substances used in construction and maintenance should be obtained from the destructive distillation of oils. The drainage of the surface of the road before anything was put down was of extreme importance. He had had trouble with roads on chalky soils on account of the porosity of the chalk. If great care were not taken on such soils the road would be wrecked. The amount of expansion and contraction due to temperature changes required, he thought, joints at intervals of 20 yards, but they need not be of great size. It was absolutely essential to lay down the bitumen carpet or concrete hot. He had made a good road for heavy traffic on a subsoil of stiff clay by putting down ordinary metal and pouring over it hot bitumen, the whole being rolled in.

In replying to points raised in the discussion Mr. Dryland said that in mixing bitumen and tar there would always be the difficulty of their difference in specific gravities. He thought the vehicle was the prime factor in forming corrugations. No better subsoil for a road could be wanted than dry chalk. The drainage must be good. In surface tarring there was no doubt accretion, but he had found that the tar did percolate as deep as 3 in.; that must have a good effect in keeping out water and holding the stones together. Waviness was at its maximum in the first six months. The new material was only partly compressed and also contained excessive oil which afterwards evaporated when conditions became more stabilised. Corrugations did not seem to alter much after the first few months, though they had a tendency to flatten out. The crests of the corrugations were sharpened by frost. There was more adhesiveness to a cold material in the case of tar and pitch than bitumen. He was afraid that any waterproof material would be more or less slippery. The trouble would be got over by educating the horse. There were practically no complaints in London where the horses had got used to asphalt surfacing. He was surprised to hear Sir George Scott-Moncrieff say that he had trouble with chalk subsoil. Provided one had a crust sufficient to keep out surface moisture he would rather have chalk foundation than any other. It was merely a question of waterproofing. There was a proposal to lay some concrete roads on the new roads being constructed out of London, in such a way that if they did not answer they might serve as a foundation for something else. He had always avoided expansion joints. There were bound to be small cracks, and he trusted to reinforcement to minimise them.

After a vote of thanks to the joint honorary secretaries of the section, Messrs. H. N. Allott, A. R. Cooper and J. S. Killick, proposed by Sir G. Scott-Moncrieff, had been passed and suitably acknowledged by Mr. H. N. Allott, the meeting was concluded.

SECTION II.—HARBOURS, DOCKS, RIVERS AND CANALS.

The section of the Conference dealing with harbours, docks, rivers and canals, reassembled on Friday, the 1st inst., under the chairmanship of Sir Maurice Fitzmaurice, C.M.G., who proposed a vote of thanks to the Port of London Authority for the courtesy extended to members of the Conference on the occasion of the previous day's visit to the new dock.

River and Estuary Problems.

Mr. C. H. J. Clayton then read his note on "The Conservancy and Maintenance of Rivers from the Point of View of Land Drainage." This note is reproduced on page 130 in this issue, together with the other notes read at this meeting. At the conclusion of his paper Mr. Clayton pointed out that, from a drainage point of view, the problem usually resolved itself into a question of the best means of getting surplus water into arterial channels, and confining it there. Sea outfall channels not uncommonly flowed through large areas of low-lying marsh land, a good deal of which was protected against tidal overflow by the erection of artificial embankments. These were useful and beneficial from a drainage point of view by reason of the fact that they did, to a considerable extent, confine the tidal and fluvial current within definite limits, and to that extent assisted in the maintenance of the gradient and depth of the bed. Valuable as those embankments were from a drainage point of view, they also

served a useful purpose from a navigation point of view, but it was quite rare to find any navigation authority having any responsibility for the maintenance of the embankments. Such an anomaly might be prevented if there was one co-ordinating authority for all purposes in a river channel.

Mr. Richard Grantham then read a paper entitled "The Effect of Sluices and Barrages on the Discharge of Tidal Rivers," and added a request to be allowed to quote an expression of opinion by the late Mr. James Abernethy, vice-president of the Institution, in reference to proposals to dockise the river Avon at Bristol. Mr. Abernethy had said: "Many important ports were situated upon tidal rivers, and he was strongly of opinion that every demand to diminish the tidal volume of those rivers should be resisted to the utmost." At the conclusion of the reading of Mr. Grantham's note, papers were read by Mr. H. Cartwright Reid, on "The Relative Advantages of Dredging and Training-Walls in Estuaries," and by Mr. G. E. W. Cruttwell, on "The Utility of Models for Estuarial Experiments." A general discussion of the four notes, which we publish on pages 130 and 131, then took place.

Mr. E. G. Crocker, in opening the discussion, said he thought the conservancy and maintenance of rivers was a subject of more than ordinary importance. It was really one of national importance. Everyone would admit the desirability of conserving rivers, not only for land drainage, but for many other purposes. He did not agree with Mr. Clayton that under-draining increased the volume of water discharged into a river during periods of large flood. Large and extreme floods only occurred in rivers when the soil had become saturated by a prolonged wet period and when the rain was flowing off the surface. Under-draining would not increase the maximum volume of water flowing into a river in a given time when the land was once saturated; in fact, under-draining produced the very opposite condition, for it took the water at the beginning of a wet period into rivers quickly, and, provided those rivers were capable of discharging that water to the sea, might prevent a big flood. Under-draining would produce more small floods in a river, and if the wet period was not prolonged, would decrease the height of small floods.

He was in full accord with the author that the rivers of this country generally required considerable improvement and should be better conserved and maintained; but he was of opinion that this conservancy should be in the interests of navigation rather than of land drainage. The increase of commercial trade by improved and cheap inland water transport was as essential to the prosperity of the country as the increase of food production.

The question of rating was one upon which there was considerable controversy, those in the uplands thinking that they should not be rated for works done in the lower part of the river, and also that those at the mouth of the river were let off very lightly. He thought the simplest form of rating would be the most effective, and that the whole of the agricultural lands in a drainage area should be rated on a flat average basis, and towns and buildings in the area on their rateable value. The present position of the river conservancy fell far short of what was required. Recent legislation had done little, if anything, to improve it. The present legislation had lamentably failed in that it did not endeavour to follow the recommendations of the various Royal Commissions which had sat in connection with the national control of rivers for various purposes.

The subject of sluices across tidal rivers was an especially fascinating and interesting one. The old sluices across the rivers mentioned in the paper were really too small to be of interest to the engineer of to-day. They all had small openings, those at Denver having the largest, these being 18 ft. in width, and being fitted with self-acting gates. Moreover, none were provided with any means for effective scouring. Hence any silting which occurred below those sluices could not be dealt with. Vermuyden, the greatest drainage expert of all time, had postulated, as the first principle of drainage, "A drain with a sluice at its outfall"; and Rennie, in 1809, followed this principle in his scheme for the drainage of the middle and south levels.

As regards the sluice across the River Ouse at Denver, he could speak with some certain knowledge, for this sluice was under his charge for nine years. The first Denver sluice was not built to keep tidal waters out of the River Ouse, but was built to prevent the fluvial water coming down the One Hundred Foot River from flowing back up the Ouse. Vermuyden never intended the One Hundred Foot River to be a tidal river, or other than a drain. Up to as recently as 1782–83 there was no tidal rise at Denver on a neap tide, and on an ordinary spring tide the rise was only 3 ft. to 4 ft. As far as he had been able to ascertain from records, no dredging had ever been done immediately below the Denver sluice; there was a small accumulation of silt below the sluice in 1912, but he was successful in removing this by scour. It took two winters to do this, whereas it could have been removed in two days had Denver sluice been fitted with proper sluice gates. Above Denver sluice the only dredging executed (until that carried out by the Board of Agriculture in 1919) was the removal of a comparatively small deposit at a cost of approximately 600*l*. The bed of the One Hundred Foot River was to-day at a level 23 ft. lower than when cut in 1663, a point of great interest and one known to very few.

In connection with the proposed sluice across the Ouse at St. Germans, that proposal was made by him (the speaker) in 1916 as the result of careful examination during the serious floods of 1914 and 1915. He was convinced that this was the only efficient and economic method of improving the drainage of the Ouse. It was no proof to say that the late Mr. Wheeler laid down the principle that any cause which obstructed the flow of the tidal water and the free propagation of the tidal wave was detrimental to the maintenance of a river in its most effective condition and led to the shoaling of the channel. No engineer could lay down any principle which was applicable to all rivers in this country. This so-called principle was no principle at all; it had become a fetish with many engineers, and had been a great hindrance to progress in the improvement of our rivers. He had never accepted it, and he intended to continue his investigations before accepting the dictum of any engineer, however eminent. The River Ouse was a river of a special character. The conditions existing in all rivers were different and must each individually be investigated.

Mr. S. Preston, in dealing with the question of rating, said that the law as it stood at present laid it down that only land which could be shown to be benefited by a drainage scheme could be rated. Up till quite recently the authorities had followed the principle that any land lower than 5 ft. above highest flood level was benefited by a drainage scheme. Within the last two or three years the Board of Agriculture had extended that 5 ft. to 8 ft. It was obvious that in many cases that gave a small area on which assessment could be realised. An instance of this was provided by the Arun in Sussex, where the rateable area of certain portions had been raised in one year to 42*s*. in the £. He was asked by the Minister of Agriculture to go down and investigate, and he found that the total catchment area of the Arun was 236,800 acres and the area on which rates were levied only 7,000 acres. By the recent alteration of the Ministry of Agiculture that area might be increased to 10,000 acres, but even then that was only about one twenty-fourth part of the whole catchment area.

Referring to the manner in which assessments were dealt with, Mr. Preston pointed out that it was the custom of Drainage Commissioners and Commissioners of Sewers to make an estimate of what they wanted to spend in any particular year, and to rate for that year, with the result that in many cases which he had had to investigate they had recovered no rates at all, and, consequently, they had no funds upon which they could draw when any work had to be done. That was not a wise course to pursue. He thought the authorities should levy a uniform rate, and if they did not require to spend it, put it aside to fall back upon when work had to be done. He thought the Ministry of Agriculture should reopen the question of fixing small assessments, and that the whole catchment area ought to pay something. A few pence per acre on the whole catchment area would not be felt by tenants or landlords, and would give 3,000*l*. or 4,000*l*., which would go a long way to help the people in the lowlands to keep the drainage clear. He did not suggest a uniform rate. The higher land should pay less than the lower land.

He thought Mr. Grantham's paper with regard to the effect of sluices across tidal rivers was too sweeping. In his view it was a matter of opinion depending very largely on the position in which the sluice was placed. He had investigated, on behalf of the Ministry of Agriculture, the drainages in Somersetshire, where there were four main rivers, the Axe, the Brue, the Carrie, and the Parrot. The Carrie and the Brue both fell into the River Parrot, and both were provided with sluices where they fell into the river; the Axe drained into Bridgewater Bay, and was also provided with a sluice at the mouth of the river; the Parrot had no sluice at all and the landowners there had pressed for a sluice to be built. All those rivers would be tidal if it were not for the sluices. He did not hesitate to say, from his own personal investigation, that those rivers were kept clear of deposit to a degree which they could not be if the tides were going backward and forward.

Mr. C. S. Meik, referring to Mr. Grantham's paper, said that in connection with the development of water power in any tidal river the most important question for consideration was the effect of any barrage upon the tidal flow. He had suggested the proposed barrage across the Severn to the Water-Power Resources Committee. One reason why he had adopted the Beachley Head site in preference to the site at New Passage was because it interfered less with the tidal flow. He had come to the conclusion that a barrage at New Passage, which was practically on a line with the Severn Tunnel, would be fatal to the preservation of the channels to Bristol and to Newport. He thought that the most tidal flow that ought to be interfered with was about 20 per cent. of spring tides, leaving 80 per cent. of the volume of water free to go up and down the river.

With reference to Mr. Clayton's paper he thought that 8 ft. above highest flood level was all right for the higher reaches of a river, but in the case of the Norfolk Broads, 8 ft. would bring enormous areas into the rateable areas of the Commissioner and would bring in also houses that were perfectly safe from flooding; in other words, they would make the people on the Broads pay for the preservation of the river in its upper reaches. He did not agree with Mr. Preston with regard to rating the whole watershed for the benefit of the people in the lower districts. If there was any risk of flooding in the lower districts those people ought to be made to pay to protect their lands. The people in the upper reaches got no benefit and he had no doubt that there would be serious opposition to any attempt to rate the people on top of a hill for the benefit of those down in the valley. The people below bought their lands with the knowledge that flooding did exist and he did not see why they should not take that risk into consideration.

Mr. J. R. Freeman (American Society of Engineers) gave an interesting account of the work he had done in connection with the Yellow River, China. At the request of the Chinese Government he had investigated the possibility of modernising the Grand Canal. An elaborate hydrographic survey had been made, four groups of gauging stations being established over a distance of about 80 miles. The bed of the river up-stream from Kaifong, 80 miles or 100 miles above the point of the great migration of the river seventy years ago, was 10 ft. to 15 ft. higher than the general level of the Delta Plain, the low water surface of the river being some 5 ft. above the bed level and the level in times of great flood as much as 25 ft. above the level of the Delta Plain. Soundings were taken, and it was found that when the river had risen 5 ft. on the surface it had also deepened its bed to very nearly an equal amount. When the flood had risen 10 ft., the river had taken a new depth, in some cases 10 ft. to 15 ft. below the depth at low water. Daily height records of the water were

taken, and also daily records of the percentage of sediment carried, and it was found that at low water the percentage of sediment, by weight, was about 0·4 per cent., but that it increased as the flood increased until at the peak of the flood the sediment reached as much as 0·8 per cent., and in some cases 1·0 per cent., of the total weight carried by the stream. The material of which the Yellow River Delta was composed was such that, whenever the velocity of the water got above 5 ft. per second, rapid erosion commenced, the river digging for itself a deeper channel. Owing to this increase in channel area, the velocity of flow never exceeded 7½ ft. per second. He had examined under the microscope several hundreds of specimens of the material of which the Delta was made, and sieved them through standard cement sieves, and he found that 95 per cent. of those samples, when thoroughly dried and without any mechanical pressing, would go through a sieve 200 meshes to the inch.

In concluding his remarks, Mr. Freeman referred to the peculiar manner in which the Yellow River had changed its course. The Chinese had records going back to 2,000 B.C., and within that time the river had been wandering in the most remarkable way: it now empties itself into the Gulf of Chin-Kiang, 300 miles or 400 miles away from where it was seventy years ago. Changes of this sort caused disaster on a terrible scale. He believed, however, that it was quite feasible to hold the Yellow River in a straight and narrow channel, and that the area of land that could be reclaimed and given increased fertility would well repay the whole cost of the improvement.

After an adjournment for lunch the discussion on these papers was continued in the afternoon, Mr. G. Abernethy saying that he desired to emphasise the opinion that his father had expressed years ago: that any interference with rivers which were dependent entirely upon their tidal capacity would be absolutely fatal. Interference not only affected the river, but more especially the entrance channel. There were hardly any rivers where interference with the tidal capacity would not bring disaster.

Mr. G. FitzGibbon pointed out that Mr. Grantham's reference to Mr. Havelock Case's report on improvements proposed for the outfall of the Ouse might lead one to believe that a sluice had been constructed across the Ouse with the sill of the sluice level with the bed of the river. Mr. Grantham should have mentioned that when the Denver sluice was constructed the sill of the sluice was as much as 8 ft. above the bed of the river. In those circumstances was it surprising that accumulation took place? Most of the instances given by Mr. Grantham were instances of sluices or tidal-doors erected from 150 to 250 years ago. There were later instances that might well have been quoted, for instance, the set of sluices across the Thames at Richmond. Those sluices were constructed twenty years ago, and when they were proposed, it was alleged that there would be such an enormous accumulation of silt both above and below that the river would be ruined. Those fears had not been borne out in practice.

With regard to the sluices across the River Ouse, Mr. FitzGibbon stated that, having studied all the conditions, he had come to the conclusion that, although some millions of money had been spent, scarcely anything had been done to diminish the frequency or the seriousness of the flooding. It therefore became necessary to try and find other means, and he was of opinion that the only remedy was to be found in the construction of proper sluices in a proper position on the river. Silting could be easily dealt with by the system of sluices proposed. There were to be 12 Stoney sluices, each 37 ft. 6 in. in width; the sill of the sluice was to be placed level with the bed of the river; the sluices were only to be closed when there was danger of flooding; at all other times the tide was to be allowed to flow freely with no obstruction whatever. In those conditions was it reasonable to say that such a scheme would be ineffective? He was surprised to find that Mr. Grantham, after going through that exhaustive inquiry, was not converted to the principles of sluices.

Sir John Griffith said that his opinion, after two years of Water Power Resources Inquiry in Ireland, was that it was necessary to have central control to determine how far the waters of the rivers must be limited to navigation, to drainage, to power, and to fisheries. With regard to the question of rating, he was of opinion that the whole drainage area should contribute to the cost of works. He maintained that the upland people, whose land was benefited by the quick run-off of water, should contribute towards the cost of the works below.

Referring to Mr. Grantham's paper, Sir John Griffith said he supported a system of sluices on the Ouse, although nobody appreciated more than he did the great value of tidal water in our tidal rivers. The problem on the Ouse was the salvation of a tremendous area of cultivable land, and he had satisfied himself that sluices could be erected across the Ouse without serious results as far as silting was concerned. He had sympathy with experimental investigation, and he thought the suggestion made in Mr. Cruttwell's paper that the National Physical Laboratory should take up the subject was a good one.

Mr. Tebbutt, of the River Ouse Commission, thought that engineers ought to come to some conclusion as to what was going to be the real effect of sluices on the River Ouse. The effect of what had been advocated in the Fen district on the mind of drainage authorities was that the tide was doing all the work and that engineers need do nothing. He did not think they would ever get the full benefit of the tide in the Ouse until dredging was done and the river put in proper condition.

Mr. W. H. Haile expressed the view that the question of irrigation ought not to be lost sight of in the discussion of barrages. The damming of the Axe, the Brue, and the Carrie, was doing wonderfully good work from an irrigation point of view. With regard to rating, the limit adopted by the Somersetshire Drainage Commissioners was 2 ft. beyond highest ascertained floods, and at the present time the district boards were themselves voting as to whether or not they should petition the Ministry of Agriculture to bring in the high lands for rating purposes. He thought that the high lands should be brought in on a *pro rata* rate, not on the full rate.

Mr. F. S. Robins stated that he thought that the tidal flow in main rivers should not be interfered with. By putting a sluice across a river, the tidal flow was eliminated at a point where the return water was most wanted. There was no possible prejudice against sluices being put at the top end of a tidal flow, where they only got the rise and flow of fluvial water. If the tide was running up at 6 ft. per second and running down at 2 ft. per second, sedimentation was bound to take place at the top end of the tide because the return water was not sufficient to carry that sediment away. Mr. Clayton had stated in his note that under-draining increased the flow of the fluvial water. There was no doubt that it had this effect, but Mr. Clayton had rather ignored the fact that it was only the average water that was brought down quicker. It was a pity that averages had been used, because they were absolutely worthless from a drainage engineers' point of view. The drainage engineer wanted to know the greatest flow in 24 hours.

Mr. G. J. Griffiths, referring to Mr. Clayton's paper, pointed out that liability for upkeep was a very controversial matter. Conditions varied greatly. In some rivers the whole watershed could be brought in; in others, only those areas that did undoubtedly derive benefit. The money required must be spread over the greatest possible area. On the question of the desirability or otherwise of a sluice on a river, he thought that each river must be considered on its merits. With a sluice a certain amount of siltage took place that would not occur if the water was allowed to pass on. He was intimately acquainted with the Severn, and agreed with Mr. Meik, that the barrage, if ever it was put up, should be at Beachley. The question of siltage would have to be seriously considered if the Severn barrage scheme was ever proceeded with.

Mr. A. J. Martin said he did not agree that it was established by experience that soil water was discharged more rapidly from under-drained than undrained lands. Efficient drainage necessitated clean ditches, the straightening and improvement of arterial drains and minor watercourses, and the removal of every impediment to the free flow of water to the river. With regard to Mr. Clayton's 8-ft. limit to the jurisdictional area, he had been responsible for the laying out of two or three score of drainage areas, and in no single case had he taken any hard-and-fast limit. He dealt with each case on its merits, the sole question for consideration being—would the land be benefited either directly or indirectly by the improvement and maintenance of the river? Referring to Mr. Grantham's statement concerning the destruction of the sluice in the River Rother, Mr. Martin stated that he had had occasion to inspect that river, in January, 1919, and he had found a sluice which had been built in 1844 in a very good state of preservation. There seemed to be an impression that Mr. Grantham had completely condemned sluices in tidal rivers. He did not think that the author had gone so far as that. There were certainly cases on record where sluices had proved harmful, but, on the other hand, there were many instances where they were beneficial.

Mr. W. M. Beckett, referring to the Severn barrage, thought it desirable that opportunity should be given to discuss the effect that a barrage would have on silting in both the lower and upper estuary. At the present time he estimated that on spring tides roughly 950,000,000 cub. yards of water passed up and down the river past the line of the proposed barrage, and 480,000,000 cub. yards on neap tides. After the barrage was erected that quantity would be reduced to about 600,000,000 cub. yards on spring tides and 250,000,000 cub. yards on neap tides. At the present time the water for the first 11 ft. on spring tide rose through a gorge some 400 yards wide and 60 ft. deep at low water, called "The Shoots." The velocity of the water through "The Shoots" was very considerable. The flood tide flowed quicker than the ebb tide and, therefore, the natural tendency was for the flood tide to take up more silt than the ebb tide brought back. That effect, he believed, was neutralised by the violent flood waters which occasionally came down and scoured out the deposit. The effect of putting in the turbines and discharging into the Shoots the volume of water from the turbines, which when they were all working would amount on a spring tide to something like 600,000,000 cub. yards in 7 hours or 8 hours, would in his opinion be sufficient to keep the channel clear.

Sir Thomas Ward said that he believed there was a great deal to be learned from models. Sir George Buchanan had described his model of the Rangoon River in his paper that had been read before the Institution. He had personally seen and used that model for settling points of discussion among engineers with regard to the fixing of groynes. In the case of the New River in Burmah a model had been constructed of the training works, and in a few hours complete agreement was arrived at. A model was a means amongst engineers of facilitating agreement. With regard to silting up below sluices he found that engineers must indicate the position where they wished the silt to be deposited. In a channel the first thing the water did was to lay down silt on the bed. If they did not want that they must put down some kind of training works and show Nature where they wanted the mud, and Nature would probably put it where they wanted it.

The meeting then adjourned to reassemble in the afternoon, the conclusion of the discussion on the morning subjects being first taken.

The afternoon proceedings were opened by Mr. C. H. J. Clayton, replying to the discussion raised by his note read at the morning session. He agreed that under-drainage of land had given rise to the necessity for larger drainage channels. He was fairly satisfied that under-drainage of land did produce the effect of a more rapid discharge under average conditions. With regard to Mr. Preston's remarks on the rating of larger areas, it might interest members to know that there was a Select Committee of the House of Lords appointed in 1877 on the Conservancy of Rivers, whose recommendation was that rivers should be brought for

drainage purposes under a central administration, and that the whole water-shed be rated for works in the river. Parliament had not given effect to those recommendations.

Referring to Mr. Meik's objection to the 8-ft. level which the Ministry of Agriculture had decided was a reasonable limit, Mr. Clayton stated that the principle upon which the Ministry had gone was that there were lands outside the flooded area which were still injured by the super-elevation of water in the subsoil.

Mr. R. F. Grantham, replying on the debate on his paper, said that he shared Mr. Clayton's view that under-drainage did send water down more rapidly to the lower levels. He thought that the works which were necessary to rivers like the Ouse would cost a great deal more than the rating of a small area of benefit could possibly afford, and, therefore, if anything was to be done it must come to a question of putting a small rate on the water sheds. He did not see how the works could be carried out unless they took in a larger area for taxation. He was very glad to hear Mr. Meik say that in his opinion the Severn barrage would produce silting and do great damage to the Severn below the barrage. He did not think Mr. Beckett's figure of 600,000,000 cub. yards as the discharge from the turbines would remove the silt, in front of the barrage. If silting once occurred the effect of letting the water down from above would only be to remove that silt a little lower down the river. With regard to the Richmond sluice, that had nothing to do with drainage; the Richmond sluices were half-tide sluices, so that there was no comparison between those and the sluice that was proposed across the Ouse. Mr. Fitzgibbons had said that the tide was to be allowed to go up the Ouse freely through the sluices except at times of very high flood. It was Mr. Stevenson's report on those sluices which had brought the question to a climax. In that report Mr. Stevenson said distinctly that the tide was only to be allowed up during summer, which was about the worst time you could allow it to flow, because there was more silt in the summer coming up the river than at any other time. Silting must occur, and the opening of the sluices only meant removing the silt a little lower down the river.

Mr. G. E. W. Cruttwell, replying to the debate on his paper, said he was glad to learn that Sir Thomas Ward had found models of use to him in his researches. He himself had certainly found the only model which he had ever made most useful. Of course, one had to see how the model compared with the actual state of affairs in order to judge whether it was reliable or not.

Mr. Cartwright Reid said he had made investigations at Calcutta, and the result indicated that the proportion of silt varied very considerably in the different depths of the river; the proportion was very much higher in the deeper parts of the river than in the shallower parts, and in some places was greater as it got deeper. He gathered from Sir Thomas Ward that experiments had been made by Mr. Kennedy in other material than the fine silt sand mentioned in Mr. Kennedy's paper. If additional experiments in other materials had been made, it would be interesting for the Institution to have particulars of them. He felt sure that the colloidal theory was one that must come very much more to the front in the future. There was evidently something in the silting of our rivers which was not fully understood, and it might be that the colloidal theory was the explanation to which they must look.

Inertia Gauges in Pile Driving and the Bearing Power of Soils.

Following the conclusion of the discussion of the notes read at the morning session, papers were read by Mr. E. Latham, on "The Use of Inertia Gauges in Pile Driving," and by Mr. A. L. Bell, on The Bearing Power of Soils." A general discussion of these two notes, which are reproduced on pages 131 and 132 in this issue, took place. The first speaker was Col. R. E. B. Crompton, who said that during the time he had been with the Road Board it had become very necessary to attempt to measure the force of impact of a wheel of a loaded vehicle striking an obstacle such as the crest of a road. They had tried all kinds of devices to get an inertia gauge which would measure that impact. The great difficulty was that it was almost impossible to make the gauge small enough and light enough; the weight of the gauge itself was a serious handicap. He wanted to emphasise the fact that research was necessary.

Mr. J. R. Freeman, desired to add his testimony as to the need for more information on the bearing power of soils. He was surprised at the small advance which had been made since the time of Rankin. As a result of the work of the Commission at Panama a new study had been evolved which he was sure would be of interest. From his investigations of the failures of a good many earth banks and retaining walls, and also of the slides of the Panama Canal, he had discovered that the line of fracture was not straight, as shown in text books, but was in a curved line. In one or two cases the rupture took place by shearing of the material; he found several places where there was a vertical slide formed in the material, although it was of a clay nature. He had made experiments to determine the horizontal pressure that resulted from a given vertical pressure. It seemed as though the angle of repose changed very greatly and suddenly according to the water content of the particles of sand, and it was questionable whether they had not again got up against the colloidable condition of these extremely fine particles.

Mr. R. A. Cummings said he had been greatly impressed by the individualistic point of view of members of the Institution. American engineers viewed their engineering problems from a different angle. American engineers proceeded along a line of collective effort rather than that of individual enterprise. The work to be done was the work of a Committee or a number of Committees to which each individual contributed his share, which was incorporated in the report of the Committee.

Mr. P. M. Crosthwaite, referring to Rankin's theory, pointed out that it was altogether based on the angle of repose, and most of the theories that had been propounded since were practically the same. He thought the Americans were the first to introduce the angle of internal friction which was a very indefinite thing. Many of the books that talked about it really used in their formulae the angle of repose. The first thing to consider when coming to the angle of internal friction was how to measure it. In all the text books he had read in which an attempt had been made to measure the angle of internal friction, it had always been done by taking a given section of clay and measuring the force required to cut it across. In the paper he read last session before the Institution he adopted another method of arriving at the angle of internal friction. That was by measuring the pressure against a wall packed with clay, and from that calculating back to what the angle of internal friction should be. At the same meeting, Professor Fullerton read another paper in which he dealt with very much the same kind of material. He measured his angle of internal friction by shearing and obtained an angle very much less than the angle of repose. Another way of getting the angle of internal friction was by measuring penetration and calculating back.

Mr. Wentworth Shields pointed out that modern practice in the design of training walls and in the design of foundations was by no means upon a satisfactory and agreed basis. He was inclined to think, however, that Mr. Crosthwaite was a little too pessimistic. After all, since the time of Rankin, a great deal had been done. He suggested following the example of their American friends, and appointing a Committee to make investigations, and to lay down certain rules based upon such investigation. The Committee would have an opportunity of investigating cases of failure, because he was sure that any engineer, whether he was responsible for a failure or not, would gladly put at the disposal of such a Committee all information about a failure. The rules that such a Committee would be able to lay down would save future engineers very many pitfalls and their work would be most valuable.

Mr. Keen-Smith said he did not think there was any place in the world where the question of clay and the banks of railways and reservoirs could be studied better than around London. They all knew the state of things they had with regard to some of the railway tunnels, and the state of things that had been produced by the drought. They had only to go to Wimbledon Common to see the cracks and to find houses where they could post a letter through the walls.

Mr. Latham, replying to the debate on his paper, hoped that the exact behaviour of a pile when driven would be investigated scientifically. He hoped that Mr. Wentworth Shields would see his way, not only to discuss retaining walls on his Committee, but would also allow people who had to deal with deep-water quays to have a chance of considering what was going to happen to a pile when driven into different strata. What he pleaded for was the principle of the inertia gauge, and he did not think it was possible to bring that down to practical politics unless a Research Committee took it in hand. There seemed to be no reason why they should not obtain almost a pocket instrument which could be attached to timber or concrete piles, by which accurate records of penetration per blow could be obtained.

He agreed with Mr. Cummings that the pile must be regarded as the medium for transmitting load to the soil. He again appealed for a Committee to deal with Mr. Wentworth Shields' very important question, and as a side line perhaps to deal with the circumstances of recording what really does happen when a pile is driven.

Mr. Bell, in dealing with the remarks passed relative to his paper, said he had always avoided the question of the angle of internal friction, because it seemed a doubtful definition; no one knew exactly what it was. His own idea was to follow out Rankin's method. He was in favour of a Committee. When drafting his paper, he felt that to discuss such various theories in short speeches would not lead to any very useful conclusion. If a Committee was appointed, he thought something might be done, and he was entirely in accord with the suggestion. Individual effort had done a great deal in the past, but it was necessary that there should be collaboration. The Committee ought to proceed not on lines of solving engineering problems but of trying to guide individual workers. That he thought was the best course to suggest.

A vote of thanks, proposed by Mr. C. S. Meik, to the Chairman of Section II. of the Conference, brought this meeting to a close.

SECTION III.—MACHINERY.

Large-Cylinder Internal-Combustion Engines.

At the meeting of Section III on Friday, the 1st inst., the chair was occupied by Sir Vincent L. Raven, K.B.E., and in the absence of the author, Mr. W. F. Rabbidge presented Sir James McKechnie's paper on "Internal Combustion Engines with Large Cylinders." This paper we print on page 132. In declaring the discussion open, the Chairman remarked that the work that had been done in connection with internal-combustion engines with large cylinders was one which would be of great interest to all marine engine builders.

Mr. Acland, who opened the discussion, said that there was one point about the data given which was rather exceptional. In most engine trials the data were incomplete on the subject of the heat passing through the jackets and passing through the piston. One found either the quantity of water given or the temperature, but seldom both. Without both it was quite impossible to analyse or compare the various engines one with the other. In the case of the high-speed engine, No. 567, Sir James gave the figures for the piston cooling, the quantity of oil, and the temperature of inlet and outlet. He had, from the data given, roughly analysed the figures for piston cooling of engine No. 567, 22 in. diam. by 22·75 in. stroke. Taking the specific gravity of the oil as 0·9 and the specific heat at 0·4, the total heat taken out through the piston amounted to 158,000 B.Th.U. per hour, or on the area of the 22-in. piston it was equivalent to 60,000 B.Th.U. per square foot per hour, or slightly over 5½ per cent. of the total heat supplied to the engine. Mr. W. J. Still had analysed

something over 100 engines on the basis of the rate of heat transmission through the walls, or through the piston, and taking only engines of over 10 in. diameter, and excluding petrol high-speed engines, there were only two engines in which the transmission was 50,000 B.Th.U. per square foot per hour. The great majority of them grouped themselves around the figure of about 40,000. Noble's two-stroke engine, which had a diameter of 16·2, gave a very high figure for rate of transmission—so high that one was rather sceptical about believing it. He had since been informed by Mr. Noble that those results were obtained on the test bed, and could not be lived up to. For constant running, the heat transmission on this engine was also about 40,000 B.Th.U. per square foot per hour. Sir James McKechnie had referred with perhaps some slight anxiety to the question of increased stresses in the metal of the cylinder due to the cyclical changes. He would remind the members present of the interesting paper published by Professor Coker and Mr. Scoble before the Institution of Civil Engineers in 1913, and of some very careful experiments made on a 7-in. by 15-in. gas engine, giving 12 h.p. at 240 r.p.m. Briefly, the result was that the temperature of the cylinder liner was very moderate. The difference between the cylinder liner and the outlet of the cooling water was 80 deg. F. and the cyclical change was negligible. The combustion chamber surface, however, was in places as much as 450 deg. F. above the water outlet. The cyclical change in that case was 36 deg. F. Though it might not be wise to generalise, he thought the point that might be taken for granted was that the cyclical changes might be neglected in comparison with the very serious differences of temperature between the inner surface of the wall and the outer surface of the wall, which increased normally with the diameter of the cylinder owing to the increasing thickness of the wall. It seemed that the solution for increasing sizes of engines whilst avoiding or suppressing very high heat stresses, which generally amounted to rather more than the pressure stresses, was to reduce the thickness of the wall. A construction which had been adopted in the Still engine was to reduce the thickness of the wall to such limits as were imposed by manufacturing considerations, and to strengthen it against the pressure stresses by ribbing it longitudinally outside, and supporting it outside the ribs with a plain cylindrical forged steel hoop pressed on. By using this construction a 22 in. by 36 in., 2-stroke engine, developing 340 h.p. at 120 r.p.m., which had been running now for nearly twelve months under trial at Messrs. Scott's, the wall thickness was only $\frac{1}{4}$ in. between the ribs, which was where the highest stress would occur. They made some experiments on a thicker cylinder which was 1 in. thick, and they found, with the high temperature of the jacket in the Still engine, a difference in temperature between the skin of the wall and the outer surface of under 50 deg. F. on the larger engine. This compared with 450° in the hot parts of the small 7-in. engine with temperatures which he was afraid they did not know, but probably increasing still more rapidly with the thickness of the cylinder wall. The rate of transmission in the 22-in. Still engine was 22,000 B.Th.U. per square foot per hour. That was an added proof of the stresses being negligible.

Mr. Restler said that on the Continent there were gas engines up to 10,000 h.p. being made—four-cylinder double-acting engines. Very little was known in this country about engines of that order or size. It would be of great interest to the members of the Institution if any information could be given on that point.

Mr. Martineau said that there was one point about which they had very little information, and on which as engine builders they wanted the help of the metallurgist and scientist, and that was on the question of materials. The real factor which governed the size of both gas engines and Diesel engines was the rate of heat transmission. The relation between the conductivity and strength of a metal was one which really affected the problem more than anything else. It would be very interesting if they could have some information as to how the conductivity of cast-iron varied with included carbon, both combined and free, because apparently the wearing surface of the cylinder got better the greater the quantity of free carbon present. In aero engines a large quantity of aluminium alloy was being used. Was there any reason why such metal or some other variation could not be used for large Diesel engines to increase the rating of the engine by the higher heat flow which was permissible? There was a great deal of information on blast-furnace gas engines given in an excellent article written by the late Mr. Walter Crook, and published last year in the *Iron and Coal Trades' Review*. It was an excellent paper giving the history of the development of gas engines up to the present period with really accurate scientific information.

The chairman hoped that they would have had there some representatives of firms who had dealt with this matter and who had built some of these large cylinder internal-combustion engines, and that they would have given them the benefit of their experience. It was not much use theorising about matters of this kind. It was much better to hear from people their personal experience as to the difficulties which always arose prominently in any new developments.

In his reply, Mr. Rabbidge said that years ago he was well acquainted with Mr. Still, and anything that Mr. Still measured up was certain to be pretty accurate. As regards Mr. Acland's remarks he did not know to which test the heat transmission figure of 60,000 B.Th.U. referred—whether it was at 340 h.p., or 400 h.p.; but it was obvious that No. 567 was a very highly rated engine. It did not, however, profess to be a commercial engine, being a submarine type, with a tremendous piston speed, and of very special design, which had involved great expense in whittling down the connecting rods. Until they had run it for some years they could not say what rating one should give it for continuous running in more or less unskilled hands. It was quite possible that for continuous running, and allowing for contingencies, they would have to reduce the rating considerably. At present, as far as he could sense the results of commercial practice, the point was not merely to get an engine to run on a test bed, but to get it to run with such a margin as to cover the hundred and one things which arose in commercial, or marine practice. For warship work the running was not so continuous, being most cases intermittent, and not at a high duty. The warship very often ran at about a quarter of her power, even assuming it was a quarter, and this was quite different from the commercial engine. If No. 567 had to be taken as a commercial engine, probably it would have to be rated lower. Mr. Restler had mentioned gas engines. At Vickers they did not profess to be leaders in the way of making large gas engines, having only taken them up comparatively recently, but they had made gas engines with 43-in. cylinders, double-acting four-stroke tandem engines. They were rated at 1,200 kw., at 100 revolutions. The construction the nothing remarkable, but care was taken with was curves in the covers and at junctions of the cylinder and their jackets. The liner was simply pushed into the cylinder and fitted it tightly. Mr. Martineau made some interesting suggestions with regard to the conductivity of metals. Aluminium had been tried for large pistons. As far as he could judge from his own experience, which was small in these matters, while one got in a petrol engine a higher rating from an aluminium piston largely on account of its getting a better charge coefficient, as it was called in aero work, they had not found there was any appreciable effect in the Diesel engines where they had applied it.

(To be continued.)

THE SWEDISH WATER-POWER ESTABLISHMENTS.—At the close of 1920, says *Swedish Export*, the aggregate power utilised in water-power stations amounted to about 1,200,000 h.p., to which must be added about 260,000 h.p. (135,000 h.p. for the State and 125,000 h.p. for private concerns) which were in course of equipment. The Government power station at Motala and the extension of the Porjus station, and also the Bergslag power station at Forshuvudfors, are approaching completion.

COLLOIDAL FUEL APPLIED TO BAR-HEATING FURNACES.

SOMETIME ago, in an article in our columns,* Mr. Lawford H. Fry, in discussing the uses of pulverised coal pointed out that such fuel was considered to have advantages over oil or coal for certain metallurgical processes. Mr. Fry states that pulverised coal, compared with oil, gives a "softer" flame, and that steel heated with it has a more "mellow soaking heat," and for this reason it is preferred by the workers. Between the two extremes, of oil on the one hand and pulverised coal on the other, is colloidal fuel, which, it is claimed, in the furnace possesses much of the softer characteristic of pulverised fuel, with the advantages in handling etc., possessed by liquid fuel.

A report has recently been brought to our notice of interest in this connection. It has been drawn up by Captain J. C. Marble on trials made on a rod-heating furnace at the Swansea Works of the Steel Company of Canada. Originally, it was the intention to make the tests at the Hamilton Works of this company, but the supply of fuel available being insufficient for a good run on large furnaces, a rather smaller furnace at the Swansea Works, Toronto, was selected for the test. The furnace chosen was one for feeding a bolt and rivet machine requiring two 22-ft. rods 1 in. in diam. per minute, at 1,800° F. Working with oil fuel, this furnace was usually operated with oil averaging 30° B., burned by means of an air-atomising system under 2-lb. pressure, when the oil consumption ran to about 28 gallons per hour, with six burners in use. Under these conditions, however, the furnace could not keep the machine fed, and there was a short enforced delay after each heat of about ten bars.

The furnace as at first re-designed for colloidal fuel was found subsequently to be capable of improvement. Under boilers this fuel produces a very long flame, and where baffles or brickwork are in the flame path and not far from the burners, there is a tendency to coke. For this reason long combustion chambers were at first provided, with arrangements for the supply of pre-heated air. The burners used were of the inside mixing type, using steam for atomising. The steam supply was drawn from a shop main in which the pressure fluctuated considerably, necessitating very nice adjustment of the six burners to secure satisfactory results, and as a matter of fact, difficulties with these burners arose from the steam choking off the fuel supply. As a result of tests it was found that the distribution of heat was not all that could be desired, and that it was not thrown effectively upon the floor. Trials suggested the shortening of the combustion chambers, which, it was thought, could be effected under these high temperature conditions without danger of coking. The burners were thereupon reduced to three, and the furnace was re-arranged as shown in Figs. 1, 2 and 3, on page 125, the alternate chambers being used as vents, as shown in Fig. 3, so that the flame was drawn down on to the floor and well distributed. No vents were provided in the furnace roof. The combustion chambers were only about 2 ft., long and were supplied with blast air through the burner opening, and also up through chequer brickwork below (Fig. 2). In the revised arrangement burners of the outside mixing type were adopted, mainly on account of the fluctuating steam pressure.

The fuel supply to the burners was arranged as shown in Fig. 4, a view of the furnace being given in Fig. 5. A supply tank sufficient for a day's run, and capable of holding about ten barrels of fuel, was used close to the furnace, as shown in Fig. 4 at *a*. From this tank the fuel was drawn by a motor-driven rotary pump running at 200 r.p.m., to supply a 1-in. pipe line *b* to the furnace. Close to the pump on the delivery side was a relief valve to by-pass surplus fuel back to the tank if necessary. The fuel passed from the pipe *b* through a heater placed over the furnace. This heater consisted of an 8-in. pipe 6 ft. long, containing four lengths of 1-in. pipe, the larger pipe being supplied with steam from the shop main. From this heater the fuel passed into a pipe *c*, from which $\frac{1}{2}$-in. pipes led to the three burners. A return line from *c* led back to the storage tank. The steam line is denoted by the letter *d*, and it will be seen that this is branched to the burners, and to the pre-heater. Air was supplied under a pressure of 2 oz. per square inch by the belt-driven fan *e*, and the 3-in. pipe *f*, to the burners as shown, and by 4-in. connections to the spaces below the combustion chambers. These air connections were fitted with regulating cocks. Each burner was arranged with a fuel regulating cock, burner valves and a cross-connection as shown. A fuel thermometer was placed in the fuel pipe just as it left the heater, and a fuel pressure gauge was also included. In the steam line there was a steam separator. By means of the cross-connections referred to above, each burner fitting could be cleared of fuel, thus preventing carbonising when standing. A small steam heater coil was placed

* See ENGINEERING, vol. cx, page 629.

BAR-HEATING FURNACE FITTED FOR COLLOIDAL FUEL.

Fig. 1. B PLAN

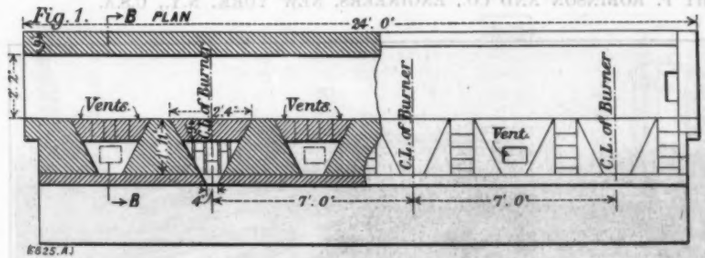


Fig. 2. CROSS SECTION AT CENTRE LINE OF BURNERS.

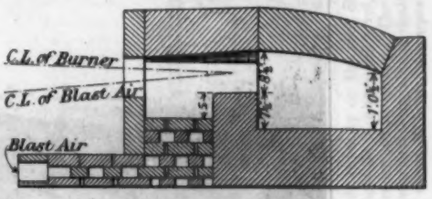


Fig. 4. DIAGRAMMATIC SKETCH OF PIPING LAYOUT.

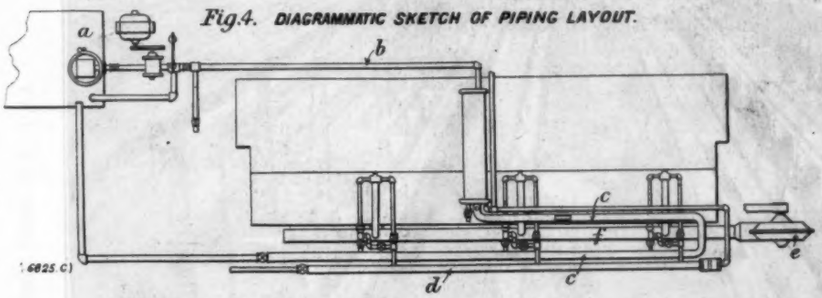


Fig. 3. CROSS SECTION AT B.B.

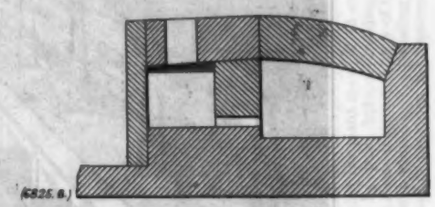


FIG. 5.

round the suction pipe in the fuel tank. A good many of the features above described will be clearly recognised in Fig. 5.

The colloidal fuel used with this plant was a quality made with topped Mexican oil of 14–16° B., and containing a 40 per cent. mixture of crude oil, coke and coal. It was prepared in September, 1919, and long standing had increased its viscosity so that it was thought as well to thin it with 20 per cent. of 30° B. fuel oil. Captain Marble states that though the barrels of fuel had stood for a long time, the test having taken place more than a year after the preparation of the fuel, no sediment was found in the emptied barrels, after being rolled to the top of the tank and tapped. The burner system was coupled up with the shop oil supply, and preliminary runs made with plain oil. This showed decidedly localised spots of high temperature near the burners. This was not the case when the furnace was turned over to colloidal fuel, when the zone of high temperature was distributed very well over the whole floor, local differences being almost eliminated. The furnace was used for heating up $\frac{7}{8}$-in. bars 22 ft. long to a temperature of about 1,500° F., the ordinary employees being utilised for its operation. As a result of runs totalling 9 hours 55 min., the consumption was found to be 30·50 galls. per hour, for 1·875 tons of steel heated per hour, or 16·275 galls. per ton of steel, the furnace fully maintaining the output desired, and the increased tonnage more than compensating for the small additional quantity of fuel consumed, as compared with the original installation. The calorific value of the fuel was 149,000 British thermal units per gallon. The fuel was under a pressure of about 20 lb. per square inch, and a temperature, pre-heated, of 200°–250° F. The steam pressure was about 40 lb. per square inch, and air pressure 2·50 in. to 4·0 in. of water.

One or two interesting points are noted in Captain Marble's conclusions. He draws attention to the fact that the fuel, though old, showed no signs of sedimentation, and that owing to its specific gravity fire risk was capable of being greatly reduced as compared with oil, by a water seal which remained separate from the oil. No trace of solid residue from combustion, ash, coke or clinker, was found after consuming about six tons of fuel. The ash seems to have been carried off through the vents, etc., without ill effects. At one time a small deposit of coke formed, but was due to the clogging of the steam line, and when this was cleared it gradually consumed away. On starting from cold, however, a slight deposit was naturally found, but this cleared when the refractory lining heated up. The wear and tear on the refractory lining is believed to be greatly lessened by the softer flame of this fuel as compared with the destructive nature of plain oil fuel. The flame can be controlled so as to be oxidising, neutral or reducing, by the ready manipulation of the air supply, and generally appears to have given very satisfactory results in this adapted furnace.

LOCOMOTIVE ASH-PIT AND COALING STATION AT COMMUNIPAW, NEW JERSEY.

THERE is a tendency on American railways to construct ash-pits at running sheds or locomotive terminals so that the hot ashes are immediately slaked, and the dust nuisance reduced as far as possible by dumping direct into water. The illustrations given herewith, on pages 126 and 127, are of a modern terminal of this description. The ash-pits in question have been recently laid down at Communipaw, on the Central Railroad of the Jersey, a point, which, on occasions, in the summer season has to cope with 380 engines in the day, the facilities of the whole terminal being designed we understand for the normal handling of about 250 engines per 24 hours. The whole terminal comprises two round-houses, together accommodating 66 engines, a coaling station capable of storing a total of 1,600 tons of three kinds of coal, delivering overhead to 10 different tracks, and the ash-pits which we propose to describe first.

A general view of these pits, which, with other features of the terminal, were designed and constructed by Messrs. Dwight P. Robinson and Co., of 125, East Forty-sixth-street, New York, is given in Fig. 1, from which it will be observed that there are two submerged pits, each with two tracks which are 200 ft. long, as indicated in the section and plan, Figs. 5 and 6. The latter figure, it should be noted, depicts one-half of the installation only. A section across the whole is given in Fig. 7, while details to a larger scale taken across the pits are given in Figs. 2 to 4, and longitudinally in Fig. 8. The two double pits consist of rectangular reinforced concrete tanks with piling foundations. The plant is spanned by an overhead crane travelling on a gantry, the lattice columns of which stand outside the engine tracks, one row being shown in the plan Fig. 6, while both are shown in the elevation, Fig. 7. A track laid between the two pits accommodates the cars into which the cinders are loaded, after excavation from the pit by a grab bucket operated from the overhead crane. The crane span is 99 ft. 6 in., while the centres of the pits are 58 ft. apart, and the centres of the tracks over each pit are 26 ft. apart. The crane runway is at a level of 26 ft. above the track.

Each pit has a width outside the walls of 32 ft. 5½ in. The side walls are 18 in. thick. The floor consists of concrete, 2 ft. 6 in. thick, with a row of piles directly under the outside walls, and also under the piers carrying the locomotive tracks (Fig. 2). The piles are spaced 2 ft. 9 in. apart crosswise, and 2 ft. 6 in. and 3 ft. apart longitudinally. The floor is reinforced with $\frac{7}{8}$ in. rods, 12 in. apart crosswise and about 18 in. apart longitudinally, and further has partially embedded in it seven lines of rails as shown in Fig. 2. These serve to protect the concrete from damage by the grab.

LOCOMOTIVE ASHPITS AT COMMUNIPAW, NEW JERSEY, U.S.A.

CONSTRUCTED BY MESSRS. DWIGHT P. ROBINSON AND CO., ENGINEERS, NEW YORK, N.Y., U.S.A.

FIG. 1. GENERAL VIEW OF THE INSTALLATION.

Fig. 2 SECTION THROUGH CINDER PIT.

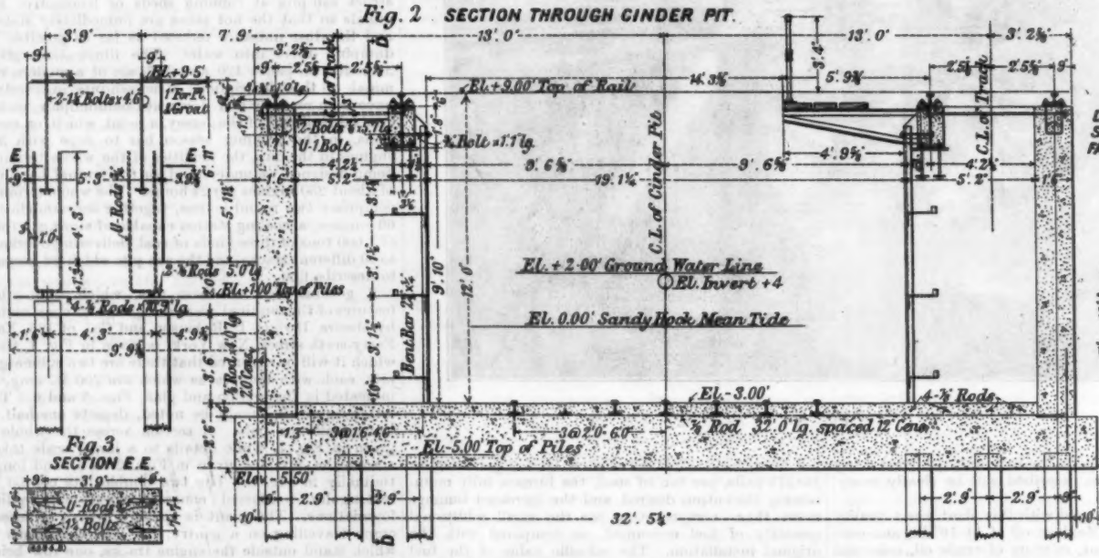


Fig. 3. SECTION E.E.

Fig. 4. DETAIL OF TRACK, STRINGER, RAIL FASTENING & ENCASING.

The longitudinal ¾-in. bars are only laid as shown in Fig. 6, at the sides. In the case of each track one rail is carried direct by the outside wall. The other rail is supported on stringers, consisting of a 12 in. by 20 in. by 120 lb. steel beam reinforced with concrete, of which a section is given in Fig. 4, and carried at intervals by buttress piers centred 14 ft. 3 in. apart. These piers are shown in Fig. 2, and in section in Fig. 8. They are 2 ft. thick. The outer corners are protected by 3-in. by 3-in. by ½-in. angles, anchored to the concrete by bent bars. Fig. 8 shows the end wall in section which is 4 ft. thick at the base and tapered to 2 ft. thick at the top, the batter being on the inside. The concrete piers for the gantry columns are shown in Fig. 2, to the left, and in section below, in Fig. 3. Each pier is carried by four piles, and contains reinforcement of ¾-in. rods bent to U-shape. The gantry columns are spaced 20 ft. apart, and there are two rows each of 13, so that the crane can run approximately 20 ft. beyond the pits at either end. The crane has a capacity of 4 tons. Two footways are carried on cantilever beams protected on the side away from the track by handrails.

The concrete throughout is of 1:2·5:5 mixture, and the designed foundation loading is 15 tons per pile. It will be noticed that the floor level is 3 ft. below mean tide level, and 5 ft. below ground water level. The hot ashes falling straight into the water are immediately quenched, and give up their heat to the water, which is thereby prevented from freezing even in the normal severe winter weather. As already mentioned, this method of treatment greatly reduces the dust trouble, which not infrequently interferes with work at ash-pits. It should be remembered that in American practice locomotives are commonly fitted with drop grates and hopper ash pans, and the laborious methods of emptying fire-boxes in vogue over here are thus obviated. In some instances the side walls of the pits are sloped so as to make the cinders move towards the centre to facilitate picking up by the grab. This, however, was not done in the installation under description, and the pits being 12 ft. deep from rail to floor, ample height is allowed for a temporary accumulation of ashes even on a considerable scale. By means of the grab, which is of 1½ cub. yard capacity, one man can easily deal with the whole of the ashes from the pits. With this arrangement as many as sixteen locomotives can have their fires cleaned and ashes dumped at once, and allowing an average of 30 minutes per engine, about 30 locomotives can be passed over the pit per hour. Should the need arise engines could be coaled by means of the grab from cars on the centre track.

The coaling-station consists of a reinforced concrete structure spanning eight tracks to any of which, as also to an additional track at each end of the building, any of three kinds of coal can be delivered. The main bunkers are arranged longitudinally in the

LOCOMOTIVE ASHPITS AT COMMUNIPAW, NEW JERSEY, U.S.A.

CONSTRUCTED BY MESSRS. DWIGHT P. ROBINSON AND CO., ENGINEERS, NEW YORK, N.Y., U.S.A.

Fig. 5. LONGITUDINAL SECTION A.A.

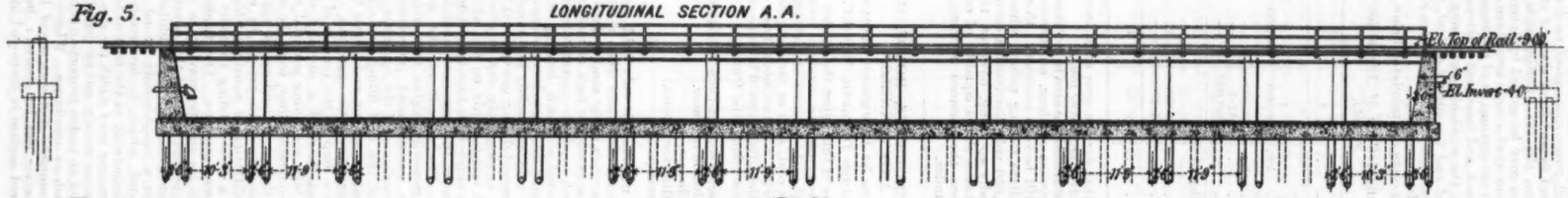


Fig. 6. PLAN C.C. (Fig. 7.)

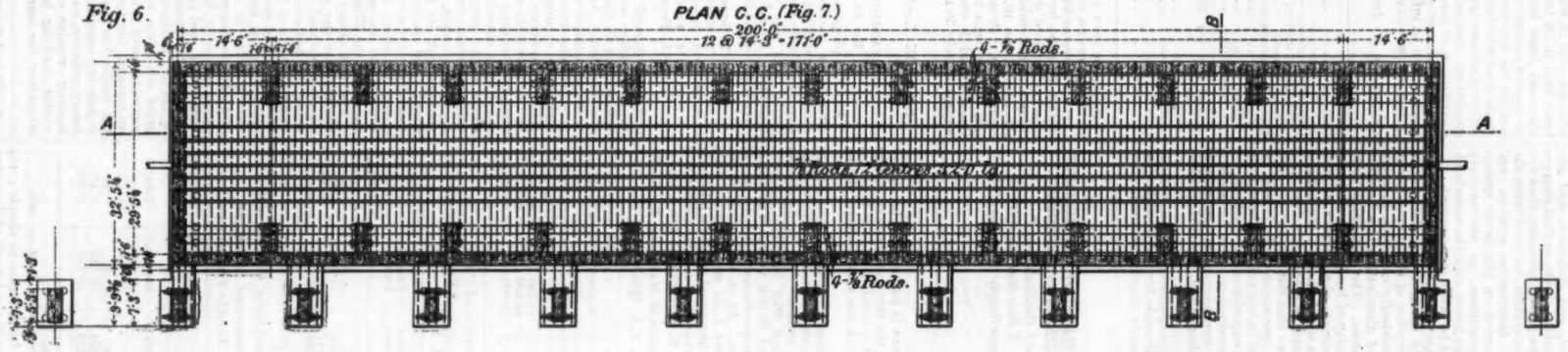


Fig. 7. CROSS SECTION B.B. (Fig. 6)

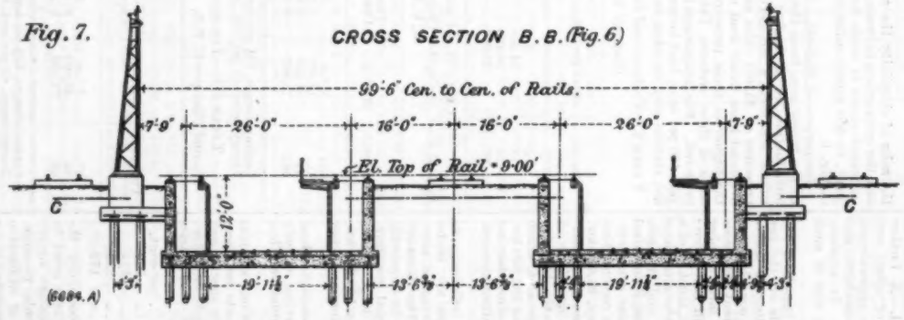
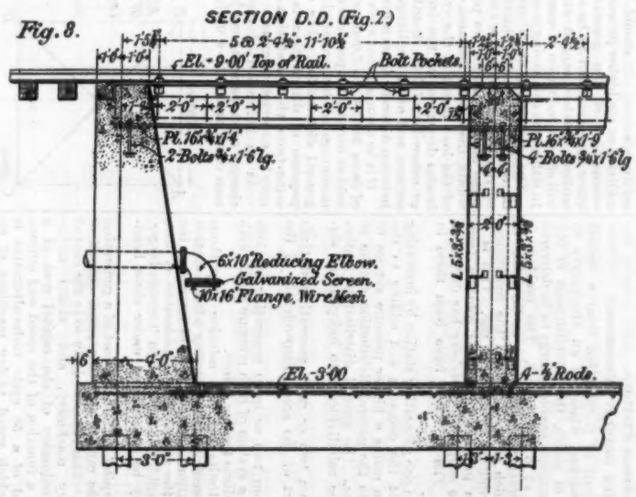


Fig. 8. SECTION D.D. (Fig. 7.)



building, and of the total capacity of 1,675 tons, space is provided for 430 tons of bituminous coal, 815 tons of broken, and 430 tons of anthracite coal. The coal is served by three chutes to each track, one for each class of coal. The building is 168 ft. in length, 34 ft. wide, and 55 ft. in height. As already stated, it is of reinforced concrete. It is carried by columns of the same construction based on pile foundations. The bunkers are carried by steel joists encased in concrete, and the hopper bottoms are of reinforced concrete and hollow brick with a thickness of 15 in. The bunkers are 19 ft. deep, the bottom being 22 ft. above the rail level. A monitor roof of steel framework extends the whole length of the building, the roofing material being of corrugated asbestos, while the side walls are of 2-in. cement plaster on expanded metal.

Coal is delivered from the cars into a pit about 100 ft. from the end of the building. This pit is also of reinforced concrete on pile foundation, and has two hoppers placed under tracks 16 ft. apart centre to centre, taking at one time two loaded cars. The coal from these hoppers is discharged by reciprocating feeders to bucket conveyor elevators. There are two such elevators, each with a chain length of 178 ft. They are parallel, 7 ft. apart and each carries 59 buckets 30 in. long by 24 in. wide, at a pitch of 36 in. These conveyors serve to elevate the coal on to two inclined 30-in. belt conveyors which carry the coal to the top of the bunker building already described. These belts are of five-ply reinforced rubber, with ½ in. covering protection. They work inside an inclined conveyor bridge structure connecting the hopper and bunker buildings, this bridge having a steel framework, concrete floor and asbestos roof. This conveying plant is arranged as two units each of a capacity of 100 tons per hour; either unit can be operated separately, or with the conveyors of the other. Unloading trippers above the bunkers can discharge into any of the three longitudinal bunkers as desired. Eleven emergency stations are arranged from any of which the plant may be shut down, should need arise, by push button. At the storage tracks for the coal cars steam is provided for thawing out coal frozen in the cars in winter.

In connection with the coaling station provision is also made to take in sand, which after cleaning and drying, is elevated from the building in which it is prepared and stored, by compressed air, to two tanks of 15 cubic yards capacity on the roof of the bunker building, i.e., about 52 ft. above rail level, from which any of the ten tracks can be served. The coaling and sanding plant described is capable of dealing with the requirements of about 30 locomotives per hour.

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ENGINEERING CONFERENCE.

SECTION VII.—ELECTRICITY WORKS AND POWER TRANSMISSION.*

THE ECONOMIC LIMITS OF DISTRIBUTION FROM COAL-FIRED STATIONS.

By WILLIAM BRADLEY WOODHOUSE.

THE economic limit of distribution from a central power station is reached when, as an alternative to further extensions of mains, the establishment of one or more additional stations enables energy to be delivered to the consumers at a lower cost. The problem is therefore a consideration of the steps to be taken to supply an area which extends beyond the economical limits of the distribution pressure in use. This is a problem which has presented itself for solution from time to time as the supply of electricity has developed over wider areas. The solutions have been three in number, namely :—

1. To supply from one generating station by increasing the output to meet the demands and adding to the original distribution mains a higher pressure system or systems feeding into the general distribution system at a number of points. The general distribution system may or may not be sub-divided into independent sections.

2. To supply from two or more generating stations each feeding a part of the area independently of the others.

3. To supply from two or more generating stations inter-connected by a system of high pressure mains with or without intermediate feeding points.

Within certain limits the first solution is without question the most economical. Starting with a station of say 1,000 kw. output, the economies of increasing the size and output of the station are considerable at first, but increase less rapidly as the station becomes larger. The economies may be summarised under three headings :—

1. *Economy of Capital.*—The total cost of a generating station increases less rapidly than the rated output of the plant installed. This is particularly so in the case of buildings, auxiliary machinery, and steam turbo-alternators. The reduction of the capital cost of a turbo-alternator is a function of the speed and output. The limiting speed of a 50 cycle turbo-alternator is 3,000 r.p.m., at which speed to-day machines of an output of 15,000 kw. may be obtained. A further increase of output involves a reduction of speed and mechanical design, and puts at present an approximate limit of 25,000 kw. to a single cylinder machine, and 50,000 kw. to a two cylinder machine. It appears, therefore, that economically the limiting size of each turbine unit is some 50,000 kw.

The above remarks apply to the plant installed, but the earning capacity of a station depends on the use which can be made of the plant after providing the spares necessary for security of supply. A brief consideration will show that the proportion of spare plant decreases with the number of machines installed. A large number of machines for the same total output will cost more ; a smaller number, to give the same security, must be of a greater total rated output. If each turbo-alternator has an overload capacity of 25 per cent., and two sets are regarded as essential spares, then the economical subdivision is into ten sets. This particular consideration is modified by the relatively high steam consumption of smaller turbines which, in a station of, say, 30,000 kw. would reduce the economical number to seven. Interconnection of stations also affects the question. A further advantage of a large station is due to the diversity of demand arising from supply over a wide area which may have the effect, as between the station of 100,000 kw. and one of 500,000 kw., of reducing the station demand by some 10 per cent., and the capital expenditure accordingly.

2. *Economy of Coal.*—The increase of efficiency as between turbines of 1,000 kw. and 25,000 kw. under similar steam conditions represents a saving of some 25 per cent. of the coal consumption. The diversity of demand referred to above has its effect in improving load factor and still further reducing the coal consumption. The economies made possible in a large station represent a further saving, but as between a 150,000 kw. station and a 500,000 kw. station the amount is not great.

3. *Economies of wages and Other Expenses.*—These economies, though marked, represent a saving on only a small part of the total costs, and are relatively less important.

Total Saving.—It is with hesitation that one submits a general figure of the savings to be made on these accounts, it being always possible to quote special and exceptional cases to the contrary. It may be taken, however, that the relative cost per kw.-year varies somewhat as follows :—

	per cent.
500,000 kw.	100
250,000 kw.	114
150,000 kw.	122
50,000 kw.	173

Cost of Distribution.—Against these economies the extra costs of distribution over the wider area must be set. The requirements of a constant pressure supply limit the radius of distribution at any particular pressure. If, as is usually the case, the pressure of utilisation and of detail distribution is fixed, then, to supply a wider area, a second system of higher pressure mains becomes necessary, from which the secondary system is supplied at a number of points. This involves capital expenditure on mains, switchgear, transformers and regulating apparatus, on which the annual charges must be met.

The new system of mains and transformers also involves energy losses in iron, copper, and dielectric, and the annual cost of these must be added to the capital charges on distribution. It should be noted, however, that the addition of the higher pressure system, by permitting the subdivision of the general distribution system, will allow a greater load to be carried on this latter system without further capital expenditure, or alternatively will effect a reduction of energy losses with the same load. In either case this saving must be taken into account.

The total cost of distribution is made up of the charges on capital, the establishment charges, and the cost of energy losses. With the exception of the copper losses, these annual charges are practically constant, in other words, the economical area of distribution is a function of the load factor of the system. The economical area is also dependent on the density of load, the uniformity or otherwise of load distribution, the number of consumers, and other conditions which make a comparison between different areas a matter of great difficulty.

If it be assumed that such an area has a density of load of from 500 kw. to 2,000 kw. per square mile, it may be said at once that a pressure of 10,000 volts has been fully demonstrated by practical experience as suitable for general distribution. The economical area for such a pressure of distribution is approximately 150 square miles from which a station demand of, say, 137,500 kw. may be expected to arise.

As an indication of the magnitude of the various charges a comparison may be made for the hypothetical case of an area with a uniformly distributed load. For

ALTERNATIVE ARRANGEMENT OF GENERATING STATIONS.
Case 1. One Station at P.
" 3. Four Stations-A,B,C,D.
Area of Supply, 600 Square Miles.

the sake of simplicity the area is assumed to be square and the comparison between the three methods of supply indicated above is made for a total area four times as great, or 600 square miles with the stations arranged as in Fig. 1.

Comparison of Methods. Case 1.—Extension of supply to the larger area from the central station involves the introduction of a higher pressure : if underground cables are used a comparison may be made between pressures of 33,000 volts and 66,000 volts. The use of overhead lines would lead unquestionably to the use of the higher of these pressures. As an indication of the costs of these systems, Tables I, II and III have been prepared. For comparison the annual cost of a kilowatt-year (60 per cent. load factor) at the busbars of a 500,000 kw. station may be taken as 8*l.* with coal at 20*s.* a ton.

TABLE I.—*Underground Cables at Maximum Ratings.*
Cost per K.V.A. Mile.

Pressure.	Cost per Mile.	Rating.	Cost per K.V.A. Mile.
k.v.	£	k.v.a.	£
11	14,000	18,300	0·765
33	18,100	48,600	0·373
66	23,000	78,800	0·292

TABLE II.—*Underground Cables.*
Annual Cost of Capital Charges and Energy Losses per K.V.A. Mile.

Pressure.	Rating.	Capital Charges.	Energy Losses.	Total.
k.v.	k.v.a.	£	£	£
11	18,300	0·095	0·085	0·18
33	48,600	0·047	0·028	0·075
66	78,800	0·036	0·017	0·053

Capital charges, 12½ per cent.
Energy losses, 60 per cent. load factor, 0·5*d.* per unit.

TABLE III.—*Transformers and Switchgear.*
Annual Cost per K.V.A. Double Transformation.

Pressure.	Rating.	Annual Cost.		
		Capital.	Energy.	Total.
k.v.	k.v.a.	£	£	£
33	48,600	0·264	0·183	0·447
66	78,800	0·299	0·195	0·494

Capital charges, 12½ per cent.
Energy losses, 60 per cent. load factor, 0·5*d.* per unit.

Case 2.—The comparison in this case is simple : the subdivision results in the loss of the benefit of diversity, in the increase of the cost of the stations and in a poorer load factor. On the other hand the expenditure on higher pressure mains and transformers is altogether avoided.

Case 3.—The comparison here made is between equal stations of equal efficiency. Where an existing system is added to, the older stations are likely to be the less efficient, and it will prove economical to deal with the basis load (high load factor) from the new stations and the peak load from the old. Considerable economies of station operation may be gained by interconnection, and for the development of a large area there seems little doubt that whether the stations be of the same class or of different classes (peak and base load stations), practical conditions such as the available condensing water, the distribution of load and the supply of coal, will compel the establishment of more than one station, and that the stations will be interconnected.

The comparative costs are tabulated below.

Comparison of Annual Costs of Alternative Schemes of Supply.

Case	1	2	3
Generating stations—			
Number of stations ..	1	4	4
Total demand .. kw.	500,000	550,000	525,000
Mains and transformers—			
Pressure .. .. volts	33,000	—	33,000
Route miles	42·4	—	60
Kilowatt miles	5,250,000	—	156,000
Annual cost per kilowatt year—			
At stations	8·00	11	10·2
Distribution	1·23	—	0·24
Total	9·23	11	10·44

It will be seen that for the area considered one large station shows an advantage over four.

If for the same total load the area is increased, and with it the distance between stations, an increase of transmission pressure will become necessary ; this will introduce also intermediate feeding points, whose effect on the cost of the 10,000 volt distribution complicates the comparison. Broadly speaking, however, the comparison on the basis taken shows equality of cost between Cases 1 and 3 when the distance between stations is approximately 30 miles.

SECTION I.—RAILWAYS, ROADS, BRIDGES AND TUNNELS.*

ADVANTAGES OF BITUMINOUS MACADAM.

By ALFRED DRYLAND, M.Inst.C.E.

FOR the purposes of this paper the Author includes all bituminous matrices used in modern forms of road construction, whether the product of destructive distillation of bituminous coal, such as tar and pitch, the residuals from oils with a bituminous base, or natural bitumens. The chief advantages of bituminous macadam over waterbound macadam arise from :—

1. Superior cementitious qualities.
2. Exclusion of water.
3. Resiliency.
4. Facility for repairs.
5. Economy.

1. Waterbound macadam is only held comparatively firmly in place under conditions when moisture is just sufficient to fill the voids in the sand or detritus between the macadam. An excess, or lack of moisture, over or under this standard, results in movements of the aggregate, causing internal attrition, tending to round the arrises, and eventually leading to loss of cohesive stability. With horse-drawn vehicles, mainly iron-tyred, the traffic had considerable consolidating powers, and waterbound macadam, except in extremely dry or excessively wet conditions, served satisfactorily on the whole to carry traffic up to a very appreciable tonnage, rendering paving only necessary under the heaviest conditions, mainly in town streets. The advent of the self-propelled vehicle, with its generally higher unit weight, greater speed, and more concentrated propulsive adhesion, caused greater disturbance of the aggregate. The weak concretive effect of the void filling was altogether inadequate to prevent movement, and rubber tyres tended to remove the filling between the aggregate.

The first effective step in the process of bituminous binding was the adoption of a dressing of coal tar, which percolated into the filling material between the stone and had considerable effect, from the action of the pitch contents of the tar, in holding the aggregate firm. It was largely assisted in this process by its power of preventing the infiltration of moisture which had previously acted as a force tending to assist movement, and also to increase attrition. The tendency of tar, owing probably to its specific gravity, is to percolate downwards, and repeated coats of this simple and comparatively inexpensive dressing, under limited conditions of traffic, produces a bituminously bound and waterproof macadam road, which, in favourable situations, serves to carry satisfactorily at the present time a traffic up to some 300 tons per yard width per day, even when the traffic has become mainly self-propelled, so long as it does not consist of an undue proportion of rubber-tyred heavy vehicles, such as omnibuses. Where the surface coating remains complete and waterproof through the winter, nothing better can be desired ; but in damp situations the tarred surface is destroyed in the winter

* Note read at the meeting of the Institution of Civil Engineers on Thursday, June 30, 1921.

* This and the succeeding Notes to page 134 were read at the meeting of the Institution of Civil Engineers on Friday, July 1, 1921.

time, and both surface attrition and disturbance of aggregate come into play.

2. To avoid these troubles and effect further adhesion and more complete waterproofing, the expedient of forming a tar concrete has been adopted, and this, when a suitable aggregate is used, has become a common form of road coating, capable in favourable situations of carrying for several years a main road traffic including motor omnibuses, and other heavy cars, aggregating 500 tons per yard width per day. On the question of aggregate for this purpose the Author unhesitatingly puts forward the view that blast furnace slag is far and away the best material for the purpose. He further asserts that a good quality limestone or calcareous sandstone takes second place, and the hardest and best granites form the least satisfactory aggregates. A tar-macadam which compacts, as slag does, into a concrete mass becomes completely waterproof.

Other bituminous methods, such as pitch grouting and so-called "asphalt macadam," which usually consists of a bituminously bound coarse aggregate base covered with a carpet of extremely fine aggregate, generally termed sheet asphalt, is completely waterproof, and although liable to shallow surface distortion, due partially to traffic displacement, but partly also to temperature changes, affords a smooth and substantially non-"attritive" surface of great durability. Granited mastic asphalt and natural rock, the latter laid in powder form, are other well-established methods of providing waterproof and durable carriageway pavings.

3. All bituminous concrete aggregates undoubtedly have a considerable measure of resiliency which enables them to endure without material damage the shocks and stresses imposed by the impact of wheels of heavy vehicles. They suffer a large amount of distortion without breaking, and have considerable powers of recovery. An interesting subject for discussion is the question of resiliency. It is often claimed that these pavements are most durable when voidless. The Author would suggest the contrary, namely, that while they are compressible, the wear from attrition is small, but when the faculty of compressibility is lost "attritive" wear becomes comparatively rapid. A case which would seem to refute this theory is that of rock asphalt, which, being formed of impalpable powder closely compacted and laid on an incompressible concrete base, would closely approach voidlessness. The Author can only suggest that there remains a small measure of compressibility in the thickness of the coating, which is generally 2 in. in depth. When the thickness is materially reduced it tends to crack and eventually break up.

4. All bituminously bound roads lend themselves to the process of patching repair, inasmuch as it is easy to cut out defective sections and resurface. The Author suggests the chief factor in this process is the provision of a sound abutment for the patches, which can be let in and the joint completely sealed. It is very difficult to effect similar repairs to waterbound macadam owing to the instability and easy displacement of the abutments.

5. Economy is found in the comparatively long life of bituminous work compared with waterbound macadam. The test of economy of a road coating, from the expenditure point of view, is gauged by the first cost and maintenance charges divided by its effective life. It is difficult to give specific instances of the relative cost of waterbound and bituminously bound roads because the traffic changes are progressive and variable both as regards weight of units and speed. Moreover, in certain cases waterbound macadam has been found entirely impossible to maintain in a state to carry the traffic satisfactorily. The Author has, however, knowledge of specific instances where slag tar macadam has been maintained for the last sixteen years at a less cost per square yard than the previous waterbound macadam surface entailed at that remote period when motor cars were few and the heavy type were unknown. Further instances are within his knowledge, where waterbound macadam from 1908 to 1911, although surface-tarred, could not be maintained for more than three years, whereas the tar macadam, which was substituted, has lasted so far ten years, notwithstanding the great increase in weight and speed of traffic, while the cost, including maintenance, would not exceed that previously incurred in maintenance in waterbound macadam.

The Author puts forward as a general proposition that the life of a well constructed bituminous road surface may be taken to be at least three times that of a waterbound macadam, that its economy is self-evident, and that it has the additional advantages of cleanliness and lessened tractive resistance.

Road Vehicles and their Relation to Road Surfaces.

By Raymond G. H. Clements, M.C., Assoc.M.Inst.C.E.

The subject touched by this brief introductory Note is of peculiar interest to-day in the light of the marked renaissance in road transport which the last two years have shown. Its value in the economics of transportation is intimate and assessable. Under discussion the subject is usually sharply divided into its two components, the vehicle and the road.

There is always a complete agreement in the unity of the problem, although each section holds that the default of the other is the real obstacle to progress. The definite purpose of these notes is to endeavour to close the gap separating these two components, and to put forward a suggestion to form the basis of a sphere of common interest and mutual progression. In its former character the road problem was simply one of horse-drawn traffic at relatively low speeds, the solution being the Telford macadam roadway under which the roads were brought up to reasonably high standard in relation to the vehicle. Road failures under these conditions took the more natural character of simple attrition and abrasion. The development of motor traction subsequent to 1900 produced an entirely different set of conditions. Road failures developed the more difficult form of collapse of matrix or binder and general surface disintegration. The solution of this problem followed along the lines of: (1) Dust palliatives; (2) Surfacing with selected materials adaptable to a colloidal or viscous binder; (3) Recoating or reconstruction to secure a tough yet elastic pavement.

The improvements effected and the variety of expedients invented and tried were largely due to the individual investigations and keenness of the road engineers to highway authorities; their efforts being later supplemented by national research work by the Road Board constituted in 1909. Up to 1913 the general impulse was in the direction of recoating upon the existing foundation or crust with tar-treated materials, and subsequent to that date good progress has been made in the use of bitumens both natural and artificial, thereby opening up a new era in the science of road construction.

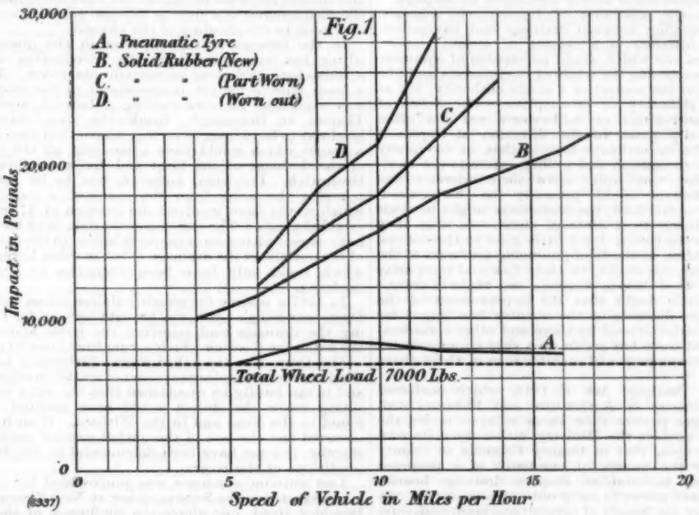
The results, therefore, very generally come to show that progress in road work has maintained a healthy and vigorous development, and road engineers, within financial limitations, have kept well abreast of the known needs of road users, certainly with respect to the normal rate of motor traffic development prior to 1914. The flow of traffic movement from railways to roads, following upon the lean years of the war, and a state of lowered vitality in roads, will call for time and patience to effect complete recovery.

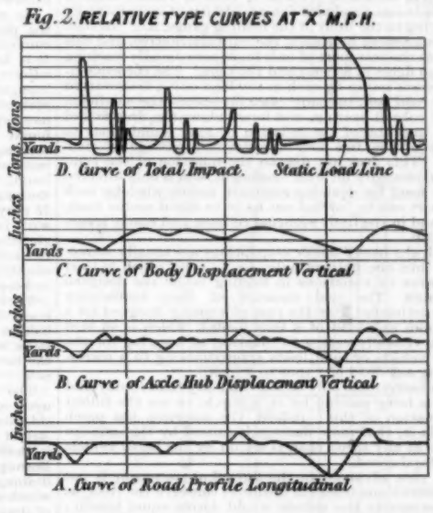
The real problem of the road engineer lies in the unknown and indeterminate loads to which his structure is to be subjected to during its effective life. This is a condition that can never truly satisfy him as an engineer, so that, even in those rare cases where he can design and build, unfettered by past conditions, the new factors which should be before him in designing are indeterminate or steadily changing. The light motor car created fresh road problems of a peculiar character, but these in turn were solved, and to-day this class of vehicle, with a 2 ton maximum axle-load, equipped with pneumatic tyres, occasions no special anxiety to the road engineer.

There is, however, an entirely different set of circumstances with respect to the road locomotive and the heavy motor car. In the case of the steam tractor, this unit has virtually stabilised as a valuable transport unit fulfilling a definite and precise purpose, but with so little mechanical growth that, with its steel-tired wheels, general absence of springing and heavy unit loads, it can be a serious factor in road deterioration. The recent tendency to mount the lighter types of steam tractor on solid rubber tyres is a notable advance. The petrol lorry, again, chiefly under the influence of the War Office subsidy, became "set" as a 3½ ton vehicle, coupled with a nominal speed on rubber tyres of 12 miles an hour.

True development of commercial vehicles in the immediate future must take into fuller account the following factors: (*a*) Development and use of resilient tyres; (*b*) Improvement in design of suspension; (*c*) Analysis of load shocks and impacts.

Now in these important essentials the design of commercial goods vehicles has shown the least real progress. True, the evolution of the passenger-carrying vehicle adapting the same chassis, engines and springs of the goods-carrying type has under the duress of commercial competition led to the general consideration of the first two factors (*a*) and (*b*) from the primary desire to study passenger comfort by means of improved suspension, and, more recently, the potentialities of large pneumatic tyres. Turning back, however, to the 3½-ton standard goods vehicle, design has already come to rest in a machine which could, for all practical purposes, be standardised from radiator to tail lamp. Apart from tyres there is no compensation to offer to the insistent





and economically sound demand for higher speeds and increased axle weights. The efficiency of the springs and the reduction of unsprung weight are two potent factors in maintenance and running costs, and determine largely the ultimate life of the machine, and precisely at this point is to be found the true contact with the work of the road engineer. The real connecting link is the question of impacts. Research and close investigation into these will produce results of the greatest value both to the wheel and the road.

Of the load shocks or impacts transmitted from the vehicle to the road or *vice versâ* no precise data or scientific records are available, and yet surely this is the dual concern of both the vehicle maker and the road engineer. Dealing with the cushioning effect alone due to the resiliencies of various wheel tyre materials, it has been deduced that the relative values of a load at certain speeds may be very generally expressed as:—

$$\text{Impact } I = \frac{W\,V^2\,H}{r} \times C$$

Where W = Weight of load,
V = Speed of translation,
H = Height of obstruction,
r = Radius of wheel carrying the load.

C is a constant for the resiliency of tyre material which appears to have the following approximate values:—

Steel tyre	= 1
Solid rubber tyre	= $\frac{1}{2}$
Pneumatic tyres	= $\frac{1}{12}$

neglecting un-spring-borne weight and spring efficiency.

A report recently issued by the Bureau of Public Roads, U.S.A., on the results obtained from exhaustive investigations into impacts from motor truck wheels at varying speeds mounted on pneumatic tyres and new and worn solid rubber tyres, contains some remarkable and fresh data which incidentally closely confirm the foregoing relativity of solid rubber and pneumatic tyres.

The curves reproduced above indicate the importance and nature of the data obtained (Fig. 1). So far these tests have not taken account of springing or unsprung weight, and it is submitted that a method could with great advantage be investigated which would provide the

urgently needed data to enable this important function of the vehicle to be scientifically adjusted.

The layout of an equipment for experimenting in this direction has already been laid before, and received the favourable consideration of Sir Henry Maybury, Director-General of Roads, Ministry of Transport. The apparatus could be put down at no large cost, and would be capable of producing scientific records which, intelligently interpreted, could directly influence design in suspension, wheel diameter and wheel tyres, the economy in material for vehicle parts, and also design in road crusts and foundation construction. Such a scheme would be less for the deduction of formulas than to secure facts and data of the values for stresses set up under conditions as closely approximating to actual running service as possible. Comparative observations could be made to record changes in stress due to variations in speed, wheel diameter, modifications of springs, and the departure of the running surface from a true plane. The data to be obtained may be best indicated by the type curves given in Fig. 2 on the opposite page. These would be self-recording and obtained simultaneously.

Without some such analysis as the foregoing it is impossible to expect the automobile engineer to secure the best life and efficiency from his machine or the road engineer to maintain the unequal contest. Already there are available surfaces reasonably flat, dustless, impervious, elastic, and wear-resisting, capable of carrying axle weights well sprung and on pneumatic tyres up to 2 tons without anxiety or concern as to speed, &c. Beyond this point you have solid rubber or steel tyres and high axle loads setting up forces which carry their shock and impact much below the road crust.

For certain heavy and bulky engineering parts such as structural members, propellers, boilers, rudder frames, &c., their size precludes the possibility of movement by rail owing to the limit of the loading gauge, &c. In such cases movement by road is the only alternative, and this involves the transport of unit loads occasionally reaching the high figure of 80 tons and 100 tons. The corresponding stresses set up by such heavy load units, transmitted to the road bed, in many cases far exceed the condition of soft subsoil bearing, and foreshadows the drastic and costly question of the redesign of road foundations to permit of the free and unrestrained passage of such loads. This does not discuss the question of the commercial necessity for such movement, and is only directed to the need for devising adequate means whereby such transport can be carried out so as to avoid undue road-wear and in the limit eventual collapse and costly reconstruction.

With the heavy motor car, springs are usually stereotyped into one pattern only, i.e., a type which is least responsive to variations in loading below the designed maximum. The real measure of their inefficiency can be estimated from the case of a spring designed for a maximum axle-load of 8 tons loaded, which is so stiff that it virtually ceases to function as a spring for the empty vehicle or light loads approximating to a corresponding axle-load of 2 tons to 3 tons.

An observer has only to stand on any road to-day and watch a lorry passing by at x m.p.h. to see the fullest confirmation of this; indeed, the assertion has much truth in it, that more damage is caused by the unladen vehicle at any speed than is set up by the laden vehicle at its legal speed.

The plea advanced in the foregoing statement is not important alone from the desire to conserve the road, as unquestionably the vehicle would derive equal benefit; replacement and maintenance would be reduced, and in time the design could be so influenced as to tend to greater economies in construction, together with a corresponding reduction in the very heavy burden of road maintenance costs, by a friendly understanding and co-operation upon the question of impacts.

SECTION II.—HARBOURS, Ddocks, RIVERS AND CANALS.

THE CONSERVANCY AND MAINTENANCE OF RIVERS FROM THE POINT OF VIEW OF LAND DRAINAGE.

By C. H. J. CLAYTON, M.B.E., M.Inst.C.E.

THE volumes of water discharged at flood periods by catchment basins in England and Wales vary from a mean depth of about 6 in. in the Midland, Southern and Eastern districts to about 20 in. in the Northern and Western parts of the country, including Wales, whilst the perennial flow of rivers may be only about 4 in. as an average.

The greater run-off to the western outfalls is due to the fact that the catchment basins lie generally to the north-west or west of the outcrop of the lias which extends from Lyme Regis to beyond Scarborough. The affected districts include the Devonian range of the West of England, the Silurian range of Wales, and the Carboniferous range of the north of England. These include the less pervious surfaces and those of more than average slope.

On the east of the lias, the mid and and eastern county districts are generally more previous and of moderately gentle slope. The run-off to the eastern out-falls is, therefore, considerably less than to those to the west.

In considering the capacity of river channels for drainage purposes it is necessary to take into account the occurrence of wide divergencies from their average run-off requirements. Whilst it would be impracticable in ordinary cases to make provision for such abnormal conditions as occasionally present themselves, it would be unsafe not to provide drainage capacity for more than the daily average run-off of the wettest period. The degree of allowance to be made has been the subject of much discussion and no little difference of opinion among engineers of great eminence and experience.

If the discharge from lands were merely that of water which either flows off the surface or through the interstices of the soil into the ditches and drains, it might be possible, as a result of a sufficient number of experiments conducted in any given area, to determine for that area a fairly safe run-off figure for the wettest period of the year; but the unknown factors of future under-drainage, the establishment of pumping machinery, or other provisions for the more rapid discharge of excess water, must still be provided against.

It is quite established by experience that soil water is discharged more rapidly from under-drained than undrained lands, and that flood conditions in the larger channels are aggravated in consequence. The fact that efficiently under-drained land is not subject to water-logging should be sufficient evidence of the necessity of larger main channels since the practice of under-drainage became general. The late Mr. Bailey Denton, in giving evidence before the House of Lords Committee on the Conservancy of Rivers in 1877, referred to water from under-drains as "new water, inasmuch as before drainage it passed off as vapour into the air." He estimated that at that time the added strain thrown upon the drainage channels of the country by the addition of this "new" water from about 3½ million acres of under-drained land, was equal to a wet year's flow of the River Thames. In brief, that another River Thames had been added to the discharge requirements of the main rivers.

It is not improbable that, since that estimate was made still another Thames had been added by under-drainage, pumping, and town and road discharges. Modern methods of roofing, paving, sewering and road construction, throw almost at once into the drainage channels very large volumes of water which would have been otherwise evaporated or slowly discharged by seepage.

As regards the possibility of improvement schemes, the present conflict between drainage and navigation-cum-milling interests is a matter of serious import. It is doubtless one which would be capable of equitable adjustment, supposing the whole of the interests could be brought within the control of a single authority, but at present the statutory or prescriptive water rights of navigation authorities or mill-owners are too often found to bar progress in the direction of improved drainage. The unfortunate fact is that in too many instances the navigation and milling interests are moribund. If they were fully alive their interests and drainage interests could generally be harmonised. If they were quite dead, the waterways might be dealt with in the interests of drainage alone. As it is, they stand astride the rivers, doing little good to themselves, but infinite harm to the food-producing resources of the country, owing, no doubt, to their financial incapacity to keep their flood sluices, channels, and banks in order.

There is little doubt that the improvement of the main drainage channels of the country has lagged far behind the needs imposed by these and other considerations, and that there has grown up a very strong case for the better conservancy and maintenance of those channels.

The Land Drainage Act of 1918, which conferred upon the Ministry of Agriculture and Fisheries considerably larger powers than those enjoyed under the Act of 1861, enables the Ministry, either upon its own initiative or upon that of County Councils or County Boroughs, or the owners of one-tenth of a proposed drainage area, to establish elective drainage boards, which shall have power to carry out any necessary works of drainage for the benefit of agricultural land, and, *inter alia*, to enter into arrangements with navigation authorities either for the execution of necessary drainage works or for the transfer to the drainage board of the whole or any part of the undertaking of a navigation authority. The Act also empowers the Ministry in cases where it is of opinion that an existing drainage authority is not exercising or is insufficiently exercising its powers, to exercise such powers itself and also any power for defraying the expenses incurred.

As regards the establishment of new authorities, the Ministry has applied as far as practicable two broad principles, namely: (1) That for administrative purposes each river system should be treated as a unit, and (2) that each portion of the area benefitted should bear some proportion of the cost of works in the main channels through and below that particular portion of the area.

Fifteen new drainage authorities, with a total area of about 700,000 acres, have been already established under this Act. The largest of these is the Ouse Drainage Board, which has a jurisdictional area of just under 485,000 acres. In each case the boundaries of the jurisdictional area have been determined by a line approximately to a contour 8 ft. above the level of the highest recorded floods.

THE EFFECT OF SLUICES AND BARRAGES ON THE DISCHARGE OF TIDAL RIVERS.

By RICHARD FUGE GRANTHAM, M.Inst.C.E.

THE history of the establishment of sluices across tidal rivers dates back for a long time, but the records do not lend much encouragement to schemes of the kind.

In the reign of Edward IV (1461–1483) a Commission of Sewers ordained that a sufficient gote or clow should be set at the outer end of Wainfleet Haven (Lincolnshire) for stopping salt water from the north part thereof. This gote or clow was erected at a distance up the Haven or River of about 2 miles from low water line of the sea. A continual silting up of the bed of the river has resulted to the injury of the discharge of the drainage water from a large area of land, the outlet from which was some distance below the clow.

In later times, in 1748, Denver Sluice was erected in the River Ouse at the junction of the old channel of the Ouse with the lower end of the Hundred Foot River up which the tide flows. Mr. A. Havelock Case in reporting on improvements proposed for the outfall of the Ouse found that the bed of the river just below the sluice was 5 ft. higher than the bed of the Hundred Foot River just opposite, a difference which must seriously impede the discharge of the water flowing through the sluice. In 1766 the Grand Sluice was built across the River Witham at Boston. The effect for some years was to cause silting-up of the river below so that in summer time the silt accumulated against the sluice to a depth of about 11 ft. This silting, however, was largely diminished by the New Cut at the outfall of the river with Boston Deeps. Nevertheless large areas some distance up the river are seriously flooded in wet seasons. Mr. Rennie, Mr. Telford, Sir John Rennie and Sir John Hawkshaw all pronounced the sluice to be a great mistake. In 1856 a dam similar to the Boston Sluice was constructed in the tideway of the Nene, 3 miles below Wisbech and about 14 miles from the sea. Two years and a half after the work was completed the silting-up of the river below it had become so serious that a mob attacked the dam and destroyed it in one night.

The late Mr. Wheeler and the late Mr. Vernon-Harcourt, in their published works, refer to a sluice called Scotts sluice, which was erected in the River Rother at Rye, Sussex, and caused much silting in the channel below. It was destroyed and the destruction produced an improvement in the outlet. They also refer to the deterioration of the channel of the River Vire, France, by the erection of tidal gates in the river. The gates were afterwards removed. Mr. Wheeler, in 1893, enunciated the principle quite clearly, and this principle was confirmed by Mr. Vernon-Harcourt, who said: "Any cause that obstructs the flow of the tidal water and the free propagation of the tidal wave is detrimental to the maintenance of a river in its most effective condition and leads to the shoaling of the channel."

In the present century interest in the question of silting has been revived by the introduction of large schemes for establishing barrages in tidal rivers. In 1904 a large scheme for the improvement in the navigation was suggested for constructing a barrage across the Thames at Gravesend. Inside the dam, navigation level was to have been 12 ft. 6 in. above Ordnance datum, a height which would have submerged all the outfalls of the drainage of the Kent and Essex marshes up to Greenwich. Provision, however, was to be made for pumping the water from the marshes, a contingency which would have involved the erection of 47 pumping establishments. The erection of the dam must inevitably have caused silting-up of the river below, to the detriment of the outfalls of the drainage of the marshes lower down, which could only have been overcome by extensive dredging.

In 1917 a scheme for erecting sluices across the Great Ouse, near King's Lynn, was brought forward for improving the drainage and relieving the lands above from the extensive flooding which occurs from time to time.

The Ouse, like the other rivers discharging into the Wash, carries a very large amount of matter in suspension, and it can hardly be questioned that the same result of silting below the sluices would have resulted as was found in the Nene and in the Witham. If such silting occurred and the bed of the outfall channel were raised thereby, it must have been detrimental to the drainage conditions of the river.

Last autumn a scheme was propounded for erecting a barrage across the Severn, either at New Passage or at Beachley Head, just above the confluence of the Wye, for the purpose of utilising the great rise of tide for the generation and distribution of power. The question of primary importance is to determine the effect of the barrage in causing silting and, if it did, the consequences of the silting.

The ordinary spring tides rise 38 ft. at Chepstow and have been known to rise to 56 ft. The flood tide flows for about 4½ hours and the ebb tide about 7½ hours. In the King Road, about 5 miles below Chepstow, springs run 5 knots on the flood and 4 knots on the ebb. The water at the mouth of the Severn with its large mud and sand banks is known to be exceedingly muddy. It is recorded that in the North Channel at the mouth of the Avon the calculated quantity of deposit within ten years over an area of about 50 acres exceeded 1,000,000 cub. yards.

In view of the experience and opinions here recorded, and of the large schemes which more recently have been brought forward, the author submits that the question of silting in the channels of tidal rivers by the establishment of sluices or barrages is of paramount importance and is well worthy of further discussion by members of the Institution.

THE UTILITY OF MODELS FOR ESTUARIAL EXPERIMENTS

By GEORGE E. WILSON CRUTTWELL, M.Inst.C.E.

1. THE experimental observation of tidal action in the Mersey estuary was first described by Professor Osborne Reynolds at the British Association meeting in 1887, and in 1889 Mr. Vernon-Harcourt contributed a paper to the Royal Society on his experiments with a model of the Seine estuary. Further experiments with tidal models have been carried out by Messrs. Kinipple, Wheeler, Robertson and others.

2. In all these models the vertical scale was necessarily much larger than the horizontal, in order to make the tidal range and surface inequalities appreciable; but it has been established that the discrepancy in the scales does not materially affect the action of the tidal currents produced in the model provided that the discrepancy is allowed for in determining the tidal period.

3. This period is deduced from the theory of wave motions by multiplying the natural tidal period by the square root of the vertical scale and dividing the result

by the horizontal scale. The average tidal period of springs and neaps may be reckoned at 12 hours 25 minutes, 44,700 seconds. If the horizontal scale be 6 in. to a mile, or 1 to 10,560, and the vertical scale 32 ft. to an inch, or 1 to 384, the tidal period of the model will be $\frac{44{,}700 \times \sqrt{384}}{10{,}560} = 83$ seconds.

4. In 1903, when the author was advising the Thames Conservancy on the improvement of the navigable channel across the Leigh Middle shoals in Sea Reach, he had a model of the river between Teddington and Shoeburyness constructed to the above-mentioned scales. Its lower end was connected by a flexible rubber joint with a movable reservoir representing the open sea which was raised and lowered every 83 seconds by four sets of rods and cranks, one set at each corner, actuated by worm gearing driven by a small overshot water-wheel supplied with water from a tap. The axle of the water-wheel was fitted with a brake-wheel, over which was passed a leather band, from one end of which was suspended a small bucket containing gunshot. By regulating the quantity of shot and the flow of water, the water-wheel could be easily adjusted to the desired speed.

5. The mean tidal range at the lower end of Sea Reach was taken at 14½ ft., represented by 0·45 in. in the model; but the reservoir was raised and lowered by twice this amount, and its area was so adjusted that a layer of water 0·45 in. deep was exactly equal to the tidal volume passing up the model. Hence, when the reservoir was lifted through a height of 0·90 in. from its low-tide to its high-tide position, the level of the water was raised through the required range of 0·45 in.

6. In order to insure the smooth working of the apparatus, the weight of the reservoir and its constantly varying contents was kept uniform by supporting the reservoir on floats having an area equal to one-fourth that of the reservoir and immersed in a fixed tank having an area equal to one-half that of the reservoir, or twice that of the floats. Thus, when the reservoir and floats were lifted 0·90 in., the water in the fixed tank was lowered by the same amount, so that the displacement of the floats was reduced by twice the amount, or by 1·80 in. Meantime, a layer of water, 0·45 in. deep, or one-fourth the reduced displacement of the floats, had passed out of the reservoir into the river above the flexible joint, the area of this layer being four times that of the floats, and its volume was equal to the reduced displacement of the floats. Similarly, the balance was preserved when the water was passing into the reservoir while the latter was being lowered. This method of balancing the reservoir was extremely simple and worked very well.

7. In order to make the working of the model as true to nature as possible, a continuous stream of water was run through a tap at the Teddington end, and another stream lower down to represent the combined inflow of the various smaller tributaries below Teddington. The inflow was discharged over an adjustable weir, which regulated the level of the water in the reservoir.

8. The directions and relative velocities of the tidal currents as observed in the model proved to be similar to the known state of affairs, and the times of high and low water at various points on the river corresponded very nearly with the actual times.

9. Experiments were made to determine the probable effect of constricting the channel in Sea Reach by means of training banks inserted in the model; but it was found that, to be of any material benefit in maintaining a deep-water mid-river channel, they would have to be constructed a long way out from the shore and at a very heavy cost, which could be more usefully expended in dredging a channel through the shoals.

10. The suggested dredged channels were formed by scooping out the sand composing the bed of the model. Although this sand was extremely fine, the grains were too large in proportion to the scale of the model to be carried along by the currents, so that no actual shifting or depositing of the shoals was discernible; but such movements were said to be clearly observed in Professor Osborne Reynolds' Mersey experiments, where the scales of the model were practically the same as those described above—possibly by reason of the greater range and velocity of the tides in the Mersey estuary. The actual velocity of the current representing a 4-knot tide in the Thames model was rather less than a quarter of a mile an hour, so it is not surprising that the particles of sand were not set in motion.

11. It would be interesting to know where sufficiently fine and light insoluble materials could be obtained which would be easily transported at the low velocities produced in the models. The value of the observations would then be greatly increased; but even without any shifting of the materials, the author considers that valuable and trustworthy information can be obtained from the models as to the probable effect of dredging, training, groynes and other contemplated works.

12. The cost of a model and the apparatus for working it is considerable, amounting to about 300*l.* in the case of the Thames model. The greater part of the model and the whole of the working apparatus could be adapted for experimenting with other estuaries at a trifling cost; so the author suggests that it would be most advantageous for the engineering profession if the National Physical Laboratory, or some similar institution, could install the necessary apparatus, which could then be adapted to suit any particular case for a moderate fee to cover the cost of the necessary adaptations and investigations.

THE RELATIVE ADVANTAGES OF DREDGING AND TRAINING-WALLS IN ESTUARIES.

By HERBERT CARTWRIGHT REID, C.B., M.Inst.C.E.

THERE is no very fixed definition of the word estuary; for the purpose of these notes it is proposed to accept it as referring to the tidal portion of a river as well as its mouth. The relative merits of any two processes must alter year by year in proportion as the progress made in either increases over that made in the other. The question is largely an economic one. With the fundamental object of amplifying shipping facilities, it may be stated thus: How can the largest, deepest and safest channel be made and maintained over a series of years at the lowest cost? The physical features of estuaries differ so materially that it is impossible to lay down universal laws in regard to their treatment, and to most general axioms there would always be a number of exceptions.

In certain cases the bed of the river or estuary consists of rock, tough clay or boulders, where dredging would be the only possible method of improvement. Even where the material is sand it has recently been brought to notice that there is frequently a colloidal precipitate, probably due to the meeting of land-water and sea-water which forms a tough crust not easily scoured by natural means until disturbed by a dredger. On the other hand, where rivers are becoming increasingly sinuous or liable to constant shifting, dredging alone would probably be "quixotic," and training in some degree would be essential.

The majority of cases, however, present features which would admit of either dredging or training being adopted alone or in combination. Amongst the principal features requiring study before dredging or training is adopted, are:—

1. Nature of mouth of river, character of bar, depth of sea outside bar, number of outlets and whether these are permanent or moving.
2. Range of tide.
3. Capacity of estuary.
4. Strength and direction of current at all times of tide.
5. Volume of upland water and amount of sediment.
6. Littoral currents and drift at mouth.
7. Nature of detritus and bottom.
8. Prevailing winds.

Perhaps the most "tell-tale" of these is the range of tide, for it is seldom any improvement of an estuary is made without immediately increasing the amplitude of the tide in the upper reaches, with a consequent increase of tidal capacity. This tends to augment by natural action the improvement already effected artificially.

Until recently it was generally theorised that to produce scour of a given material a certain mean velocity was all that was necessary. Kennedy's experiments in India have now proved that there is a critical mean velocity below which accretion takes place and above which scour commences. This critical mean velocity varies with the depth of the channel. Kennedy's results have been based upon experiments in fine sand silt, and require further datal experiments in their application to other kinds of detritus, but the principle as enunciated by him is widely accepted. Though the experiments were conducted in fresh water canals with comparatively uniform velocities, they must be also applicable to estuarial circumstances, where all the conditions of velocity, depth and direction vary with the tide. It would appear that a mean velocity, which would just prevent silting in a channel of a given depth, would require to be increased by approximately 40 per cent. if that depth were doubled. The increased scour which is observed to take place at the beginning of the flow and near the end of the ebb is thus explained by the water being shallower at these periods.

In recent years there has been a constant and well-marked development of dredging plant, and dredgers specially adapted for cutting and maintaining navigable channels of estuaries are now being designed and built that were not available a few years ago. The newer type of drag suction hopper dredger of large size (3,000 tons to 4,000 tons capacity), fitted with powerful propelling machinery strong enough to drag the suction head through the material to be removed, dispenses with moorings and their attendant loss of time, loads the the hopper with the smallest admixture of water, and increases the effective navigable depth with the minimum quantity of material removed and at a low unit cost.

Advances of this character in dredging plant put a new aspect on any comparison of the relative advantages of dredging and training works in the treatment of estuaries, and it is very probable that training schemes carried out in the past would now be more economically treated by dredging. The advantages of dredging may be summarised as follows: (*a*) Immediate advantage of increase of depth and definite results in depth and width; (*b*) can be carried out gradually and experimentally; (*c*) tends to combine the ebb and flow current in the same channel; (*d*) helps to keep the level of the river below the banks; (*e*) can be economically combined with reclamation; (*f*) is economical in first cost.

The disadvantages are: (*a*) Where strong littoral currents exist maintenance cost may be excessive; (*b*) in many other cases a considerable amount of maintenance is required; (*c*) traffic is obstructed by the dredging plant.

Training works, on the other hand, have advantages and disadvantages in the converse.

Although in some instances training-walls and groynes can be commenced in isolated parts, as a rule a complete scheme is necessary, and this must be finished before any material benefit is obtained; it also requires a long and indefinite time to attain the essential depth. The works are inelastic and, with a growing demand for deeper water, may be out of date in a few years. There is always a risk that training works, efficient in one part of an estuary, may cause a reciprocal deterioration in another part. On the other hand, training work in its very essence carries with it an element of permanence. The first cost is naturally high, being represented in a completed scheme, apart from the annual cost of repairs, by the capital sum expended.

In the majority of cases the problems to be solved in improving an estuary can be dealt with by properly-designed dredging plant. The work can proceed in graduated steps, and this method may properly be adopted in the first instance, unless the interest on capital of alternative training works is substantially less than an annual sum representing the interest on first cost of dredging added to the annual maintenance cost.

THE USE OF INERTIA GAUGES IN PILE DRIVING.

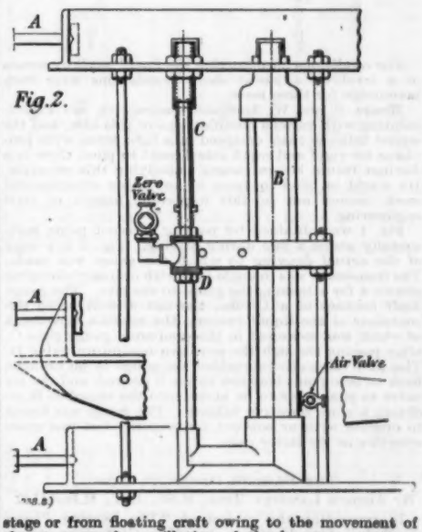
By ERNEST LATHAM, M.Inst.C.E.

FOR some years the writer has been interested in recording the "set" of piles driven in connection with marine works, and in relation to the safe load such piles can be relied upon to carry. In the post-war design and construction of deep-water quays in tidal waters he has recently dealt with deck loads up to a maximum of 14 cwt. per square foot, and the subject is of importance, while no doubt other engineers engaged on marine works have obtained data of value. The time seems opportune for discussion, and possibly research, in this direction, as pile driving is of such wide application in all parts of the world, especially where utilised to secure foundations for marine works.

In driving test piles very careful observation of the driving is necessary, as in driving from a "springy"

Fig. 1.

Fig. 2.



stage or from floating craft owing to the movement of the stage or the oscillation of the barge or pontoon, it is difficult to measure the actual penetration per blow which it is essential to observe closely in the case of test pile driving from the moment when the pile begins to "pull up."

In driving permanent piles it is unfortunately necessary for practical reasons to average over a number of blows: this is common practice, but there are technical objections to it as, if a pile has pulled up hard, this may obviously have occurred on the first one or two of a series of blows, and the balance of the series (before driving is stopped for the purpose of observation) may result in the destruction of the pile head, or, in certain cases, especially in reinforced concrete piles, even in the destruction of the pile itself.

There are various formulæ in use purporting to give relationship between safe load and "set," notably the Wellington formulæ, that published by the British Steel Piling Company, and certain empirical formulæ evolved as the result of experience. In the latter respect the writer now works to a tabular record prepared from actual observation, coupled with a simple equation and factor varying with the observed set and conditions.

The above principles must not be applied to quickly operating single-acting steam or pneumatic hammers or to double-acting hammers of the McKiernan-Terry type. These types are of doubtful value in heavy pile driving such as is experienced in marine works, and, in any event, more has yet to be learnt about the "equivalent" performance of these hammers before anything in the nature of formulæ can safely be applied to them.

The use of the word "set" is perhaps too loosely applied, and little investigation seems to have been made into the phenomena which actually occur each time a pile receives its driving blow. Fig. 1 shows an actual autographic curve taken on a test pile driven at Greenhithe,

Kent, in February of this year (1921). This is an exact reproduction showing initial "set," the vibrations which occurred on the Oregon pine pile itself, and the gradual "upwards" recovery presumably due to the partial elasticity of the clay and ballast through and into which the pile was driven. This diagram was taken by Mr. P. Meate, M.I.Mech.E., on river works being carried out under the writer's supervision.

Considerations of this character and the marked difference between "initial" or "actual" set and the observed set (always much less) led to attempts to design and test an inertia gauge.

It is a curious fact that in such a common operation as pile driving so widely applied and utilised, no serious attempt has apparently been made to design a suitable gauge for the purposes of making such measurements. This has probably been due to the obvious and inherent difficulties of subjecting a delicate instrument to the severe shock and jar of pile driving and to the difficulties of obtaining a suitable fixed point against which to measure the downward movement of the pile per blow under vibratory conditions.

Trials were made with a gauge which for experimental reasons was designed on the lines of Fig. 2. The basic idea of this gauge was relative movement between a liquid and solid—a non-return valve and a compensating chamber to renew the supply of the liquid medium between each blow. The gauge was, in fact, found to be too heavy (59 lb.), causing motion between pile and gauge which seriously interfered with the observations. The "dead-beat" action of the gauge, however, was most clearly marked, and, after various makeshifts had been attempted with a view to securing the gauge rigidly against the pile, consistent readings were observed until the gauge failed by fracture of the gauge glass.

The following are the actual observed and consistent readings:—

Penetration Recorded by Gauge (inches).	Observed Set (inches).
1	1 1/16
1	1
1	15/16
1 1/8	1
15/16	1
7/8	7/8
1/4	1/2

The conditions for observing the final "set" by means of a level on adjacent shore foundations were very favourable for these tests.

Messrs. P. and W. Anderson, contractors, are experimenting with various modifications of this idea, and the writer believes that, designed in a light form, with provision for rigid and rapid attachment to piles, there is a distinct future before gauges embodying this principle. He would be glad to know of any other experimental work carried out in this important branch of civil engineering.

Fig. 1 was obtained by passing a pencil point horizontally across a pile during driving. Fig. 2 is a copy of the actual drawing to which the gauge was made, The framework was in angle-iron with ordinary clamping screws A for attaching the gauge to the pile. The gauge itself consists of a U-tube, the one arm B being the container of the liquid (water), the relative movement of which was measured in the graduated gauge glass C, after passing through the sensitive non-return valve D. The zero valve shown enabled the gauge to be brought back to zero point between blows, if desired, and the air valve to enable air to be blown into the chamber B, to obtain a more sensitive balance. The gauge was found to operate with or without air pressure, but was more sensitive in the latter case.

The Bearing Power of Soils.

By Arthur Langtry Bell, M.Sc., B.A., M.Inst.C.E.

In presenting the subject of "The Bearing Power of Soils" for discussion by this Conference, there is no need to lay stress upon its importance, for upon that all are agreed. It will better serve the purpose of introduction briefly to review the past history of the subject as a guide for future action. Time will not permit of detailed discussion of the various theories which have, from time to time, been advanced to determine the supporting power of foundations and the pressure and resistance of earth. The application of these theories to the complex conditions of practice is difficult, and it cannot be said that any one of them commands general confidence even in the simplest cases. The bearing power of soils cannot effectively be considered alone. It is inseparably bound up with the general theory of earth pressure. We are thus compelled, if useful conclusions are to be attained, to embark upon a much wider inquiry than that circumscribed by the consideration of foundations alone.

The earliest theory of earth pressure which has left an abiding mark on English practice is that of Charles Augustin de Coulomb, a French military engineer (born 1736, died 1806). Briefly, he showed that the maximum pressure upon the back of a wall would be exerted if sliding took place upon the sloping plane surface which bisects the angle between the vertical back of the wall and the plane of natural repose of the earth behind the wall. The surface of assumed sliding (which passes through the heel of the wall) is known as the plane of rupture. This readily applicable theory is still widely used.

The methods pursued by Coulomb influenced the work of immediately succeeding investigators, but in 1857 Professor Rankine broke new ground when he published his celebrated theory of the frictional stability of loose granular material. Unlike his predecessors, he proceeded by means of a solitary principle, namely, that "the resistance to displacement by sliding along a given plane in a loose granular mass is equal to the normal pressure exerted between the parts of the mass on either side of that plane, multiplied by a specific constant." The specific constant is the coefficient of friction of the mass and also the tangent of the angle of repose. By mathematical deduction from this principle he established formulas not only for the actual lateral pressure of dry granular material, but also for its maximum lateral resistance and its supporting power as a foundation. Rankine's and Coulomb's theories still dominate English practice.

In 1876 Professor J. Boussinesq published his memoir "on the equilibrium of pulverulent bodies"—a work of great value which, perhaps owing to its profundity, has exercised but little effect on practice.

In 1881, Sir (then Mr.) Benjamin Baker read a paper before the Institution of Civil Engineers on "The Actual Lateral Pressure of Earthwork," calling attention to the serious divergence between facts and the conclusions of the theorists. His paper, though mainly destructive in its tendency, was valuable in directing attention to the need for further investigation. In this respect it was immediately effective, for in 1882, Mr. (later Sir) George H. Darwin contributed to the Institution the results of experiments on a small scale made five years earlier on the pressure of sand. These experiments were considered by their author to confirm Boussinesq rather than Rankine. They had a special value in demonstrating the influences of the degree of compression of the mass and of the mode of deposition or "historical element." He concluded, however, that under the circumstances then existing the best practical course which engineers could pursue was to work with Coulomb's rule and allow a large margin for safety.

In the same year Herr Forchheimer published particulars of further experiments devised to ascertain not only the lateral but the vertical pressure exerted by dry sand. Working with alternate layers of coloured and uncoloured sand, and adopting the expedient of saturating the mass, after deformation had taken place, with melted paraffin which, upon cooling, cemented the grains together, he was able (by sawing the resulting solid) to disclose the lines of slip which had occurred in the uncemented material. His experiments confirmed the existence of Coulomb's plane of rupture.

The succeeding twenty years appear to have yielded no further progress towards a solution of these problems, but in 1902 experiments by Dr. George Wilson on sand in a closed cylinder showed the remarkable effect of moisture upon the ratio of conjugate pressures. When dry sand was used, the mean ratio coincided closely with that calculated by Rankine's formula.

In 1911 Professor Cain read before the American Society of Civil Engineers a paper on earth pressures on tunnels and retaining walls, in which he pointed out that Sir Benjamin Baker had used, for comparison with observed facts, a theory which neglected both cohesion and wall friction—an observation which lays bare the root cause of the lamentable lack of agreement between facts and the conclusions drawn from the theories in ordinary use.

In 1915 the writer contributed to the Institution of Civil Engineers formulæ based upon shearing experiments on clay, for the calculation of the lateral pressure, lateral resistance and supporting power of coherent material. These formulæ, in the extreme case when cohesion becomes zero, coincided with Rankine's, which, as already stated, postulate a material without cohesion. Since 1915 further experiments on clay, sand and earth have been made in this country by Mr. Ackermann, Mr. Crosthwaite and other workers in this field.

A special committee appointed by the American Society of Civil Engineers to codify present practice on the bearing value of soils for foundations has been at work for several years. Valuable work has been done, a number of interim reports have been issued, and the investigation is still proceeding.

This, in brief and necessarily incomplete outline, represents the progress of inquiry in the subject now under consideration. The Conference is invited to discuss, not the abstruse technicalities of the rival theories which, it will be agreed, can most effectively be treated mathematically in written communications, but what can best be done to place practice upon a satisfactory and agreed basis. Attention is particularly directed to the circumstance (not peculiar to this particular problem) that advance, where it has been made, has been in the main the result of individual experiment and speculation. It is therefore reasonable to think that the best hope for the future lies in the encouragement and aid of individual inquiry. As engineers we seek a sound and preferably simple theory which can be successfully applied not to one only, but to all of the multitudinous varieties and conditions of soil with which we have to deal.

SECTION III.—MACHINERY.

Internal-Combustion Engines with Large Cylinders.

By Sir James McKechnie, K.B.E., M.Inst.C.E.

For powers used up to the present the success of the marine internal-combustion engine in a number of makes can be deduced from widely-published records. In addition, the facts that repeat orders have been given, and that the power of the engines and the size of the motor vessel has been gradually increased, must remove the last vestige of doubt that the marine oil engine is proving commercially, as well as mechanically, the correct solution for many propositions. For warship work the advantages have long been recognised, and the use of such machinery is now becoming generally much more favoured for mercantile marine conditions. Abnormal conditions in the shipbuilding world during the war, and for some little time afterwards, tended to a comprehensible if not altogether excusable reluctance on the part of shipowners to embark on any machinery installation presenting points of novelty to them. High costs and trade depression in turn are now restricting shipbuilding output, either steam driven or fitted with internal-combustion engines. Nevertheless there are distinct evidences of a general appreciation of the latter type of machinery, orders for motor vessels in some cases being carried on while similar steamships have been cancelled. Moreover, so completely has the point of view changed, that prospective owners are now seeking to investigate the possibilities of marine internal-combustion installations of much greater power than have hitherto been fitted in the mercantile marine, and engine designers and builders are being encouraged to prepare designs suitable for the largest and speediest vessels to be constructed. When shipbuilding output becomes normal once more it is evident that a growing proportion will be devoted to the construction of motor ships, and the present appears a suitable time to consider some of the questions which arise when high powers are involved.

It will be well at the outset to reiterate the obvious statement that the requirements in machinery for ordinary commercial vessels are very different from those in warships and in comparatively light fast craft. The modern internal-combustion engine aims at a higher mechanical standard than was attained by the steam reciprocating machine of a few years back. A comparison between experiences on high duty trials of the two classes of machinery brings this point vividly to one's cognisance. It is possible, as a result of this and of the overload capacity of internal-combustion machinery, for internal-combustion engines, relatively of the high duty type, to run trials at powers far beyond what they can, in the present state of the art, be expected to maintain with reasonable upkeep in mercantile conditions, and thus disappointment is possible unless a close analysis of the pressures, taking into account the cycle on which the engine runs, the speed, weight and other relevant points, is made. The internal-combustion engine, both oil and gas, received setbacks in its early days from the neglect of some makers to allow a reasonable margin for long running and for contingencies, and it will be found that the most successful commercial types are now sold at a moderate rating.

In considering large internal-combustion installations the electric drive, in which is fitted a number of oil engines driving dynamos which supply current to a few motors on the propeller shafts, has advocates to whom the success of the large turbo-driven electric drive in American warships has given much encouragement. The subdivision of the oil-driven generating plant in the internal combustion scheme obviously leads to greater electrical complication than when a single turbo-generator is used for each main shaft, but as far as can be foreseen the proposition is quite practicable. Again the efforts in the direction of development of a practical internal-combustion turbine are of interest, and the possibility of a successful design being evolved is not to be overlooked, difficult though the problem is.

Direct-coupled reciprocating marine oil engines are at present running with cylinders of close on 30 in. in diameter, and while published reports vary in particulars, it would seem that with a stroke of just over 45 in. these four-stroke cycle engines develop at 115 r.p.m., an indicated horse-power of 375 per cylinder, or with eight cylinders and a mechanical efficiency of 75 per centum, a shaft horse-power of 2,250 would be obtained.

Gas engines of the four-stroke cycle type are now made in double-acting units with cylinders extending up to 51 in. in diameter, so that even taking into account the higher cylinder pressure and temperature of the oil engine, there seems no reason to assume that oil engines cannot be made with larger cylinders if the demand arises.

For such large cylinders the thicknesses must be considerable in order to withstand the stresses due to the pressure. The heat stresses in particular parts, combined with the pressure stresses, complicate the problem of determining the most desirable thicknesses, even if the material is assumed to be subject to a uniform flow of heat during combustion, as in a boiler furnace plate. Seeing the rapidity with which the cycle is completed in the cylinder of a fast-running internal-combustion engine, and the intensity of transmission of heat, there seems room to doubt whether the effect on the material is not more severe than this assumption would give, the variation of temperature, though part at least of the material, being first from the flame and then from the surface layers of the metal to the cylinder contents. The temperature stress in cylinder parts has been a subject of discussion on many occasions, and it would be most useful for the design of large cylinders if reliable data were available as to the actual behaviour of loaded scantlings subjected on one side to rapid and extreme variations of temperature.

The choice of material will require particularly careful study in large cylinders, though it is useless to specify a composition to closer percentages than can be relied upon in the foundry practice, or to use metal which is likely to result in castings which are liable on occasion to be unsound with the methods followed. The meticulous methods practicable for small repetition parts are not yet in their entirety commercially applicable to such large castings, and it will be for the maker to determine within certain limits what mixture best suits his design and resources. Makers of experience now appear to have succeeded fairly well in obtaining satisfactory materials, the cast-iron in general being of a low phosphorus quality, and attention is being more particularly concentrated upon the detail of the design.

For very large powers with direct drive at a limited number of revolutions per minute, the two-stroke engine

INTERNAL COMBUSTION ENGINES WITH LARGE CYLINDERS.

APPENDIX II.—ENGINE NO. 567. 340 B.H.P. Report of Trials at Various Powers including Overload. Date of Trial 19/1/21.

Time.	Counter.	R.P.M.	Load.	B.H.P.	Timing Gear.	Spray Valve. Opens.	Spray Valve. Closes.	Spray Valve. Nominal Lift.	Pressure. Lb. per Sq. In. Fuel Oil.	Piston Cooling.	Bearing Oil.	Circ. System.	Water Exh. Valve.	Temp. Exh. Gases.	Remarks.
a.m.						deg.	deg.	in.						deg. F.	
—	—	180	167	50·0	Normal	4 A.T.C.	44 A.T.C.	0·010	2,000	—	—	—	—	—	Exhaust invisible.
9.50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10.5	—	200	480	(A) 160·0	Normal	2 B.T.C.	11 A.T.C.	0·0315	3,500	—	—	—	—	—	Exhaust very light and good.
10.20	222,385	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10.25	223,323	375	640	(B) 400·0	Normal	7·5 B.T.C.	16·5 A.T.C.	0·0775	6,500	45	12	2·5	12	1,508	Exhaust light and good, practically the same as full power trial, 18/1/21.
10.30	224,259	—	—	—	—	—	—	—	—	—	—	—	—	—	
10.35	225,196	375	642	(C.) 401·2	1 deg. retarded	7 B.T.C.	18 A.T.C.	0·0805	6,500	45	12	2·5	12	1,544	

(A) Run for 25 minutes. (B) Run for 5 minutes working up to full power. (C) Run for 10 minutes.

Fuel oil used, American distillate. Specific gravity = 0·882 at 60 deg. F. Flash point = 196 deg. F. (Close.)

ENGINE NO. 567. 340 B.H.P. Report of 6 Hours' Shop Trial. Date of Trial 18/1/1921.

Time.	Counter.	Revolutions per Minute.	Load.	B.H.P.	Fuel Oil Consumption. Lb. per Hour.	Fuel Oil Consumption. Lb. per B.H.P.	Pressure. Lb. per Sq. In. Fuel Oil.	Piston Cooling Oil.	Bearing Oil.	Circ. Water. System.	Circ. Water. Exh. Valve.	Temperatures, F. Piston Cooling Oil. In.	Piston Cooling Oil. Out.	Circ. Water. In.	Circ. Water. Out.	Bearing Oil. In.	Bearing Oil. Out.	Crank-Case.	Atm.	Temp. Exh. Gases. F.	Quantity of Piston Cooling Oil Circulated.
a.m.												deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	deg.	Gallons per hour
9.10	149,025	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
9.40	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10.10	153,064	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10.40	158,660	374·0	560	349·1	150	0·429	5,750	35	14·0	3·0	12	68	95	46	68	55	60	65	55	1,292	800
11.40	169,897	374·6	560	349·6	154	0·440	5,700	30	14·0	2·5	12	73	113	46	77	59	80	72	54	1,292	—
p.m.																					
12.40	181,145	374·9	568	354·9	156	0·439	5,700	15	13·5	2·5	12	70	118	45	77	60	87	78	56	1,310	—
1.40	192,420	375·8	560	350·7	154	0·439	5,700	40	15·0	2·5	12	66	122	45	77	59	89	82	56	1,310	800
2.40	203,712	376·4	560	351·3	154	0·438	5,700	35	14·5	2·5	12	64	125	45	72	62	92	82	53	1,292	—
3.40	214,999	376·2	560	351·1	156	0·444	5,700	20	12·0	2·5	12	64	131	45	77	62	94	84	52	1,292	800
Average		375·3	561	350·9	154	0·438															

I.H.P. = 429·3. Dynamometer constant = 1/600. Timing gear, "Normal." Fuel oil used—American distillate.
Spray valve control set at 27, opens at 6·5 deg. B.T.C.; Closes 16 deg. A.T.C.; Lift = 0·065 in. Specific gravity = 0·882 at 60 deg. F. Flash point = 196 deg. F. (Close.)

REMARKS.—Exhaust light and good. A small reduction of fuel consumption would result if allowance were made for uncollected leakages from the system. No attempt was made on this trial to cut down the circulating water supply so as to reduce the fuel consumption. The exhaust temperatures were taken in the unjacketed exhaust pipe only 9 in. from the cover.

APPENDIX III.—1,000 B.H.P. SINGLE CYLINDER OIL ENGINE. SUMMARY OF TRIALS. NO. 428. Trials Commenced 6/9/13. Finished 16/9/13.

Trial.	Injection Air Pressure.	Scav. Air Pressure.	Fuel Oil. Lb. per B.H.P. Hour.	Lubricating Oil. per Hour. Bearing.	Lubricating Oil. per Hour. Cylinder.	Circulating Water per Hour.	Total E.H.P. for Auxs.	Notch of Fuel Lever.	Position of Timing Gear.	R.P.M.	B.H.P.	I.H.P.	Indicated M.P.	Efficiency.	Piston Cooling per Hour.
				gallons	gallons.	gallons.								per cent.	gallons.
30 hours F.P. ..	1,037	4·9	0·4061	6·483	0·87	11,252·8	381·7	16	9·5	140·6	1,056·86	1,119·06	123·78	94·45	1,389·6
90 hours 4/5 P...	1,014	4·6	0·3632	7·51	0·749	11,959·5	384·7	12	5·0	126·38	852·97	913·17	112·4	93·37	1,406·8
30 hours 2/5 P...	1,002	4·6	0·3535	5·316	0·653	9,011·6	375·29	10	3·0	111·4	619·15	682·64	95·36	90·69	1,326·26
16 hours F.P. ..	1,056	4·9	0·4019	8·687	1·9312	11,205·3	297·31	15	9·5	140·45	1,036·19	1,122·09	124·68	92·36	1,448·5
73 hours end (full power) ..	1,079	5·0	0·4079	11·7	1·301	11,404·5	293·8	15	9·5	141·17	1,041·8	1,125·8	124·11	92·53	1,423·7
6 hours 2/5 P. ..	919	4·62	0·3633	6·5	0·583	8,463·0	342·9	8	4·5	99·28	436·01	478·43	75·0	91·1	1,721·0
6 hours 1/5 P. ..	854	4·5	0·367	1·16	0·541	8,435·0	347·5	5	1·5	75·30	217·36	239·78	49·5	90·69	597·6
6 hours low P.	900	3·65	0·5395	—	0·466	—	—	3	0·5	50·75	74·68	86·6	26·33	86·24	—

APPENDIX IV.—M.V. SCOTTISH STANDARD. Engine No. 580. Starboard. Shop Test (10/5/21.) Full Power.

Time.	B.H.P.	R.P.M.	Control Lever Notch.	Pressure. Lb. per Sq. In. H.P. Fuel.	Circ. Water.	Piston Cooling.	Bearing Oil.	Starting Air.	Temperatures. Deg. F. Piston Cooling Discharge. Cyl. 1.	Cyl. 2.	Cyl. 3.	Cyl. 4.	Cyl. 5.	Cyl. 6.	Bearing Oil Disc.	Circ. Water. Inlet.	Circ. Water. Outlet.	Remarks.
a.m.																		
8.30	—	—	14	4,000	14	18	17	580	101	102	103	105	101	104	60	56	70	Total i.h.p. = 1,760.
9.0	1,347	120·0	14	4,000	16	18	15	580	106	104	106	110	109	105	63	52	76	
9.30	1,342	121·8	14	4,000	16	18	17	580	104	104	104	104	104	103	66	53	78	Exhaust Analysis. CO_2 8·2; O 9·3; CO nil; H nil; CH_4 nil
10.0	1,349	120·8	14	4,000	16	18	16	580	105	105	105	105	104	105	70	56	81	Temperature = 968 deg. F.
10.30	1,338	119·8	14	4,000	17	20	15	580	103	102	103	104	103	103	72	58	82	
11.0	1,338	119·8	14	4,000	17	19	14	580	101	102	103	103	103	103	74	56	81	Total i.h.p. = 1,702

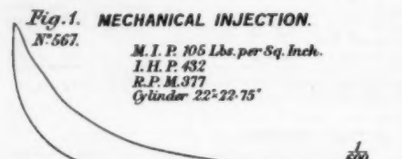
Average r.p.m. for 2½ hours taken from counter = 120·6. Average b.h.p. = 1,342·8.

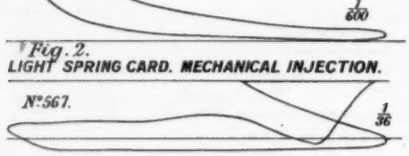
11.10	—	*Slow Running (Ahead).* 40	5	2,000	18	21	15	Fuel oil used—Anglo-American Diesel Oil. Specific gravity = 0·876 at 60 deg. F. Flash point = 188 deg. F. (Close.)
11.18	Engine	reversed						
11.19	—	*Slow Running (Astern)* 44	5	2,000	17	20	15	The engine was put over from astern to ahead several times, firing each time, then stopped.

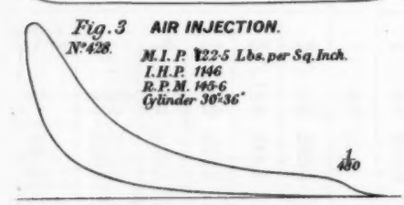
appeals to many as the first solution. It is in this type that the heat conditions are the more severe, however, and imply a lower rating. In the comparative lack of lengthy sea experience of large two-stroke engines at full power in mercantile conditions, the power which may safely be taken from a given cylinder is not so firmly established as in the case of the four-stroke engine.

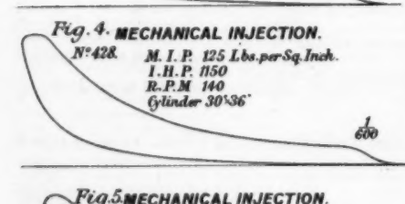
In some two-stroke designs the cylinder cover, which has often been the weak spot in that type of engine, has been brought to a very symmetrical shape, the scavenge air being introduced through the lower extremity of the liner, while in others, of the opposed piston type, the cylinder cover is avoided altogether. The liner, however, or its equivalent, and the piston remain. Ribbing of the highly-stressed portion of the liner by external circumferential rings is fitted in some designs, and it will be interesting to see if this eventually results, in large cylinders, in any small deformations of the bore in wake of the ribs.

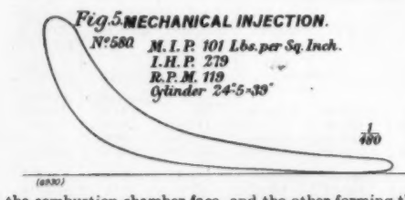
The building up of the cover from two members, one either a plate or a shallow water-cooled box forming











(6930)

the combustion chamber face, and the other forming the body of the cover clamping the former in place, has been recently proposed by various designers. Such a cover was used by Vickers in their 30-in. diameter by 36-in. stroke single-cylinder two-stroke cycle engine, which in 1913, on a run of 73 hours developed 1,042 b.h.p. at 141 r.p.m. In this case the cover was closed at the bottom by a forged steel plate, 2 in. thick, except in the way of the scavenge valves, where it was bossed up to 3 in. thick, allowance for expansion between the two parts being given. The Germans, in their high-duty submarine engines, used forged tops for their oil-cooled pistons, and these seem to have worked satisfactorily.

Apart from the normal running pressures, the parts of a Diesel engine may in certain circumstances be subjected to severe loads on starting, which will doubtless be relatively more serious in large engines. When controlled at the fuel pump, there is in the ordinary air injection engine a quantity of fuel virtually out of control between the pump and the cylinder, and this may easily give rise to excessive and very sudden pressures which might largely be prevented by spray valve control during starting.

The 30-in. cylinder referred to above is believed to be the largest Diesel engine unit in this country. The engine in this case is of the crosshead type, running at a moderate speed. An example of the high-duty crosshead type is afforded by an engine 22 in. diameter by 22½ in. stroke, which was designed to develop 340 b.h.p. at 375 r.p.m., and built at Barrow. This engine was run through an official trial of 6 hours at 350 b.h.p., after which the power was increased to 400 b.h.p. without visible distress or foul exhaust. This engine was fitted with the Vickers' mechanical injection system. The high piston speed in this engine naturally necessitated careful design of the reciprocating parts.

In the above remarks an attempt has been made to touch upon some of the more salient points which arise when debating the subject of large powers, in the hope of giving rise to the discussion so healthy in all questions of development.

Typical indicator cards and summaries of some of the trials of the engines referred to, and also of the Vickers' "Narraganset" type commercial marine engine with a 24½-in. cylinder are shown in Figs. 1 to 5, the particulars of the engines being given in Appendix I. The mechanical injection indicator card for No. 428 engine was one obtained when applying this system to the engine subsequent to the air injection trial, while the light spring card of the high duty engine No. 567 is one obtained at full power.

I am indebted to Engineer Vice-Admiral Sir George Goodwin for permission to publish these data so far as they refer to Admiralty trials.

APPENDIX I.

PARTICULARS OF INTERNAL-COMBUSTION ENGINES WITH LARGE CYLINDERS.

Engine No. 567. (Single cylinder) :—
Four-stroke cycle—trunk piston—mechanical fuel injection.
Cylinder diameter, 22 in.; stroke, 22½ in. Designed revolutions per minute, 375.
Summary of results—Appendix II. (See page 133.)
Typical indicator cards—Figs. 1 and 2.
NOTE.—All auxiliaries independently driven.

Engine No. 428. (Single cylinder) :—
Two-stroke cycle. Crosshead type. Scavenge valves in cylinder cover.
Air injection.
Cylinder diameter, 30 in.; stroke, 36 in. Designed revolutions per minute, 140.
Summary of results—Appendix III. (See page 133.)
Typical indicator cards—Figs. 3 and 4.
NOTE.—Air compressors, scavenge pump, circulating pump, and lubricating pump, electrically driven.

Engine No. 580. (Six cylinder) :—
Four-stroke cycle. Crosshead type. Commercial marine type.
Mechanical fuel injection.
Cylinder diameter, 24½ in.; stroke, 39 in. Designed revolutions per minute, 118.
Summary of results—Appendix IV. (See page 133.)
Typical indicator card—Fig. 5.
NOTE.—All auxiliaries independently driven.

CATALOGUES.

Fibre Pinions.—A 28-page catalogue giving full particulars of fibre pinions has been issued by the British Thomson-Houston Company, Limited, Rugby.

Waterproof Cement.—A compound for rendering cement and concrete waterproof is explained in a special catalogue received from Messrs. G. and T. Earle, Limited, Wilmington, Hull.

Hand Trucks, &c.—A new 64 pp. catalogue of hand trucks, barrows, carts, ladders, &c., in a great variety of extremely useful forms, has been issued by Mr. H. C. Slingsby, 142, Old-street, London, E.C.

Machine Running Recorder.—A little instrument for recording the stopping times of machines, motor vehicles, &c., is described in a booklet received from Bramco 1920), Limited, St. Nicholas-street, Coventry.

Grinding Attachment.—A grinding spindle and frame for attachment to the tool post of a lathe and operated by belt drive is described in a catalogue received from Messrs. G. W. Dowding and Co., 66, Victoria-street, London, S.W. 1.

Sheet Metal Work.—A pamphlet giving a large amount of useful practical information on methods of working aluminium sheets and strip has been received from the British Aluminium Company, Limited, 109, Queen Victoria-street, London, E.C. 4.

Electro-Medical Apparatus.—A portable electrical transformer unit which can be easily moved about on wheels and connected to any wall plug is described in a catalogue received from Messrs. Watson and Sons, Limited, Kingsway, London, W.C. 2.

Silo Construction.—Plans and description of a concrete grain silo containing 32 storage bins, each 13 ft. square in plan and 88 ft. deep, erected by Messrs. J. and W. Stewart, 12, Berkeley-street, London, W. 1, are given in a very interesting booklet to hand from that firm.

Milling Cutters, &c.—A catalogue of milling cutters, hobs, thread mills, reamers, drills, &c., issued for the export trade by the Birmingham Tool and Gauge Company, Grove-street, Winson-green, Birmingham, is very well arranged with numerous illustrations and complete tables of dimensions and prices for each article.

Motor Omnibus.—Messrs. John I. Thornycroft and Co., Limited, 10, Grosvenor-place, London, S.W. 1, have issued a catalogue of standard motor coaches having many advantages, including a very neat and smart appearance. The single-deck covered type seems to be preferred, but open coaches with adjustable hoods are made in four modifications.

Concreting Plant.—A considerable range of mixing, elevating, conveying and tipping machinery for concrete has been issued by the Ransome Machinery Company, Limited, 14, Grosvenor Gardens, London, S.W. 1. The appliances include the towers, hoists, chutes, &c., for distributing the freshly-mixed concrete in place either in road construction or building work.

Steel Tubes.—A neatly-arranged list of drawn steel tubes ranging from ¼ in. to 2 in. in diameter, and of various thicknesses, has been received from the Perfecta Seamless Steel Tube and Conduit Company, Limited, Plume-street, Birmingham. The tubes are suitable for cycle, motor and general construction work, and dimensions, weights, prices, &c., are clearly stated for each size.

Water Power and Wind Power.—Messrs. Hay, Maryon and Co., Limited, 14, Bride-lane, London, E.C. 4, send us a handsome new catalogue in which diagrams of 15 types of water motor form a kind of preface, followed by detailed illustrations and descriptions of several varieties. The 15 types are described as a few standard arrangements, and the firm are willing to assist prospective clients to select one best suited to their needs. Windmills are also dealt with in the catalogue.

Lathes.—An extension-gap lathe made by the Barnes Drill Company, U.S.A., is described in a catalogue sent to us by Messrs. Alfred Herbert, Limited, Coventry, who are agents for the tool in this country. In this lathe the shears are arranged to slide longitudinally on guides on a lower bed, and by this means the width of the gap, which is 5 in. deep, can be varied at will. Two sizes are listed, with 7-in. and 11-in. centres, and they are supplied with various attachments for general work.

Transformers.—The three-phase transformers for rotary converters made by the Metropolitan Vickers Electrical Company, Limited, 20, Brazennose-street, Manchester, are explained in leaflets to hand from that firm. Another leaflet received deals with a transformer for underground use in collieries. This transformer is portable and is fitted with rollers for running on rails. It has a fender base extending sufficiently to protect the cooling tubes and connections, which are such that soldering work underground is not necessary.

Toothed Gears.—Worm and spur type reduction gears built into housings for attachment to electrical and other motors, are dealt with in a catalogue to hand from Messrs. Henry Wallwork and Co., Limited, Redbank, Manchester. Various standard forms ranging in capacity from ½ h.p. to over 50 h.p. are listed, and particulars are also given of designs for much higher powers. A second catalogue relates to hob gear-cutting machines made by the firm, and the various tools and supplies necessary for cutting spur and worm teeth and worms.

Circulating Pumps.—Centrifugal circulating pumps driven by steam engines are made in sizes capable of handling from 1,000 gallons to about 6,000 gallons per minute are described in a catalogue received from Gwynnes Engineering Company, Limited, Hammersmith, London, W. 6. A smaller series for handling under 200 gallons to over 1,000 gallons per minute, is also listed. The impellers are of gun-metal, the pump shafts of forged manganese bronze, and the casings may be of cast-iron or gun-metal as required. The engines are of the vertical type, and either open or enclosed.

Pulverised Coal.—The method of firing coal in the form of a spray of fine powder which has frequently been referred to in these columns is the subject of a catalogue to hand from the Fuller Engineering Company, Allentown, Pa., U.S.A. The catalogue deals with plans for drying, breaking and pulverising the coal to an impalpable powder and spraying it into furnaces of watertube boilers. It is claimed that a fourth of the coal can be saved and that the cost of pulverisation, which is 1½ dols. a ton for 20 tons a day, falls to ½ dol. a ton for 400 tons per day. The present time is particularly opportune for considering the subject of fuel economy.

Cranes.—A very comprehensive catalogue of cranes has been issued by Messrs. Butters Brothers and Co., Glasgow. The sections or chapters are on: (i) Steam and electric derrick cranes; (ii) electric gantry and dock cranes; (iii) locomotive and wharf cranes; (iv) electric overhead travelling cranes; (v) hand cranes, including derrick, wharf and portable types; and (vi) miscellaneous appliances such as foundry cranes, electric winches and oil-engined winches. A number of line illustrations of the detail construction are given, but these form a small proportion of the whole and are somewhat marred by excessive reduction. On the whole, however, the catalogue is a very creditable production, which will be of service to all crane users.

Primary Cells and Batteries.—Four catalogues from Messrs. Siemens Brothers and Co., Limited, Woolwich, London, S.E. 18, deal with a very great variety of primary cells and batteries of the dry and fluid types. Clear illustrations are given of each type with full information as to sizes, parts, supplies and special uses, as well as all necessary commercial particulars. The main catalogue of 88 pages covers the whole subject completely, while two other catalogues deal with special types selected from the main catalogue, one being devoted to wet Leclanché cells. The remaining catalogue relates to dry cells, and has been specially prepared to supply information as to the most widely-used types, in a form convenient for those who are not familiar with the technical aspect of the matter.

Water Supply.—A strongly-bound octavo handbook of water supply machinery, dealing with raising, storing, purifying and distributing water has been received from Messrs. Hayward-Tyler and Co., Limited, 99, Queen Victoria-street, London, E.C. 4. A great deal of useful technical data and practical information gives the handbook a considerable value as a reference volume. A remarkable feature is the wide range of types of motors and pumps used in this service and for the illustration of apparently antiquated forms side by side with the most highly efficient developments. Two series of windmills ranging from ½ h.p. to 8 h.p. in 15 powers, with pivoted sheet steel vanes, are dealt with, and these can often be used with advantage; water, air, steam, gas and electric motors are also referred to, each being the best type to employ under some particular conditions. The price of the catalogue is 3s. 6d., and it will prove especially useful to those responsible for water supply in sparsely-populated areas at home and abroad.